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A CYBERNETIC ANALYSIS OF THE APPLICATION
OF MIL-STD-1567A, WORK MEASUREMENT, TO
WEAPON SYSTEMS ACQUISITION MANAGEMENT

THESIS

Daniel R. Vore, Captain, USAF

AFIT/GSM/ENC/90S-33

DEPARTMENT OF THE AIR FORCE
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Wright-Patterson Air Force Base, Ohio

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WEAPON SYSTEMS ACQUISITION MANAGEMENT

THESIS

Presented to the Faculty of the School of Systems and
Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Systems Management

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September 1990

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Foreword

I first became interested in the subject of Work Measurement in DOD contracting while managing the TR-1/U-2 Aircraft procurement program out of ASD/RWQC, the Tactical Reconnaissance Program Office under the Reconnaissance Programs Directorate in ASD/RW. The prime, sole-source contractor for the aircraft was Lockheed Advanced Development Projects (ADP), The Skunk Works, in Burbank, California. It was during my tenure as program manager that MIL-STD-1567A became mandatory and a late-breaking requirement on the Fiscal 85, Lot 6 aircraft production contract. At the time, we were just beginning negotiations for Lot 6, having completed our fact-finding and proposal evaluation.

Work Measurement posed several problems for the negotiation of the Lot 6 contract. First, we were the first and only customer of Lockheed ADP who required Work Measurement. Although a sister division, Lockheed Georgia was using Work Measurement, ADP had virtually no direct ties to the experience gained in this endeavor; the two divisions are essentially separate companies in their management association, style, and structure. Second, the fabrication of TR-1/U-2 parts in Burbank (the aircraft were assembled at Air Force Plant 42, Palmdale, California) was accomplished as part of a large-scale, integrated shop-floor operation comprised of all ADP contracts; MIL-STD-1567

imposed a unique manufacturing labor accounting system which would have to be integrated into existing operations. Lockheed ADP's inexperience with Work Measurement, coupled with the intricacies of introducing a new and separate system into the integrated fabrication processes, made contract pricing of Work Measurement a near impossibility. In addition, we represented at the time only about six percent of the overall ADP business base. Also, at the time of the Lot 6 negotiation, the current configuration of the U-2/TR-1 had been in production for over five years and production of the original U-2 dated back over 25 years. Cost performance on Lots two through four indicated substantial underruns in contract price (the contracts were FPIF).

In the end, after nearly 18 months of effort in evaluating Lockheed's existing manufacturing labor analysis system (predominantly Line of Balance), and preparation and revision of numerous waiver request packages, a program waiver was granted to the TR-1/U-2 production program. Cost/benefit analysis had conclusively shown that over 400 more aircraft must be built to recoup investment costs for work measurement on the TR-1/U-2 program. At the time, we were only programmed to build 10-12 more aircraft. The entire exercise had left the distinct impression that something was amiss in the Work Measurement policy within Air Force Systems Command.

Reassigned within ASD/RWQC to manage the Low-rate Initial Production (LRIP) effort for the Commanders' Tactical Terminal (CTT), a joint Army/Air Force program, with the Air Force as lead developer, I had my second experience with MIL-STD-1567A. Taking over the program just prior to releasing the LRIP Request for Proposal (RFP), I found that the questions concerning the applicability of Work Measurement to the LRIP had never been fully answered due in part to the volatility of the program and its origins as a proof-of-concept demo only (the demo surpassed expectations and the program demands had outpaced its own evolution).

Once firm direction on quantity and budget was given for CTT LRIP, we verified that CTT did, in fact, fall within the applicability criteria of MIL-STD-1567A. The unique twist was that the Army was to assume full production management responsibility following Air Force award of the LRIP contract, and the Army did not recognize MIL-STD-1567A as a valid program requirement. In fact, they flatly stated that they would delete Work Measurement from the contract once it was turned over to them.

This time, unlike the TR-1/U-2, after over six months of evaluation and requesting a waiver, the Air Force was directed by SAF/ACB to implement a tailored version of MIL-STD-1567A on the CTT LRIP Contract despite our cost/benefit analysis showing that nearly 500 CTT systems must be built to recoup investment costs. At the time, we had direction to

build some 30 systems, with no guarantee of ever reaching full production. In the end, the basis for this cost/benefit analysis was refuted by SAF/ACB after having passed through HQ AFSC/PK. Hence the refusal to grant a waiver. Again, something was definitely amiss. Out of this was born a thesis....

Daniel R. Vore

4 Dec 89

Acknowledgments

I wish to express my sincere appreciation and heartfelt thanks to my wife, Patti Jo, without whose encouragement and countless, selfless hours at the computer this thesis would have never gone to print. Also, to the folks at Systems Exploration, Incorporated, many thanks for the generous use of your equipment to make this publication possible.. I also wish to express deep and sincere appreciation to Captain Norah Hill who spent over a year walking with me down this research road. Her encouragement, energy, and commitment to excellence in helping to discover the meaning in Stafford Beer's works made this thesis possible. Finally, I want to thank my thesis advisor, Professor Dan Reynolds, who set us on this path in the first place. His enthusiasm, dedication, and capacity for being a true educator have opened many new doors for this humble student.

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Abstract

This thesis examined the role of MIL-STD-1567A, Work Measurement, from the theoretical perspective of Stafford Beer's Viable System Model (VSM) and Eliyahu M. Goldratt's Theory of Constraints. The research method involved a detailed literature review of Work Measurement, managerial cybernetics, and the Theory of Constraints (TOC) as the basis for a cybernetic analysis of MIL-STD-1567A according to Beer's methodology for diagnosis. In accordance with the principles of Beer's VSM and Goldratt's TOC, the requirements of MIL-STD-1567A were found to constrain the autonomy of the defense contractor beyond that required for systemic cohesion in the acquisition process. Other problems noted with Work Measurement included its paradigmatic disposition toward suboptimization and focus on cost as the primary measure of performance, contrary to present Total Quality Management (TQM), TOC, and VSM precepts. Also, Work Measurement's algorithmic approach to management control, combined with the failure of the DOD to establish a viable defense market, was found to preclude the defense contractor from deriving criteria for viability. A cybernetic control mechanism, in place of the orthodox methods like Work Measurement, was developed and recommended for further study via a pilot program.

A CYBERNETIC ANALYSIS OF THE APPLICATION OF
MIL-STD-1567A, WORK MEASUREMENT, TO
WEAPON SYSTEMS ACQUISITION MANAGEMENT

I. Introduction

A. General Issue

Management's charge is to create an organizational structure and environment which allows the organization to achieve and maintain viability. We adopt here Stafford Beer's definition of viability to mean the capability of the organization to maintain a separate existence within a specified, external environment or metasystem (8:113). Subsumed within the ensurance of viability, is a primary responsibility of management: to maintain stability, regardless of the process being managed. Managers everywhere must be able to distinguish between stability and instability (both actual and incipient) and to influence, or control, their system to achieve stability; which will involve control of a portion of the organization's external environment as well. To achieve stability, management must select key elements, or outputs of the system, monitor variation of these key outputs, analyze key output variances to assess common and special causes of variation, and take appropriate

action to drive the system toward stability by eliminating special-cause variation and reducing common-cause variation to a level indicative of systemic stability. Almost without exception, management fails in these endeavors due to the lack of a unifying, systemic management paradigm.

Numerous management philosophies have recently emerged in recognition of the failure of traditional management, especially western management, which generally speak either to product quality improvements or to shop- and manufacturing-floor management techniques. W. Edwards Deming (13) and others have espoused statistical process control (SPC) aimed at reducing process variability as a means of improving product quality (25:541-547). Armand V. Feigenbaum originated the concept of Total Quality Control (TQC) to identify customer quality requirements up front and maintain close interaction with the customer throughout the product lifecycle to insure continued customer satisfaction (25:544). Kaoru Ishikawa developed Quality Control (QC) circles to allow workers and management to jointly solve quality problems (25:545-546). Philip Crosby attacked the traditional view that quality improvements must always raise manufacturing costs and purported instead a quality goal of zero defects (25:546-547). Other well-known, more all-encompassing shop-floor management philosophies include Just-In-Time (JIT) (25:262-272), Total Quality Management (TQM)

(TOC), and, most recently, Eliyahu M. Goldratt's, Theory of Constraints (TOC) (18).

What each of these new management philosophies have in common is a paradigmatic disposition toward what Goldratt would call suboptimization, or local optimization relative to the system as a whole. Each approach concentrates on the improvement of some aspect of the manufacturing process, whether improved quality, lower inventory, reduced leadtimes, etc., without regard to system-level, or global, optimization. As it turns out, many of the local optima can favorably influence other aspects of the system, most notably Goldratt's TOC approach, but the systemic result of an amalgam of suboptimization routines does not guarantee viability. All of these new management techniques fall short of ensuring global optimization to achieve and maintain viability. The result inevitably is stagnation of efforts at system improvement, and a constraint on the organizational capability to adapt to a dynamic environment, which will eventually render the system non-viable.

Viability requires a system-level ability to adapt, which means that management must possess a viable system model, or paradigm so to guide and foster management's ability to assist the organization to adapt. According to Beer,

A question often asked is this: if we are dealing with an organization that is actually there to be investigated, then surely it is by definition a viable system -- and nothing remains to be said?

[However] the fact that the societary system is there does not guarantee that it will always be there: its days may well be numbered The fact that it is there does not prove that it is effectively there . . . nor efficiently there Monoliths and monopolistic systems in particular often operate at the margins of viability Moreover, many such are operating at such an enormous cost that they are becoming less and less viable in front of everyone's eyes.

One of the main reasons for this, particularly in the social services, is that people looking for cheaper ways of doing things attempt to repeal the Law of Requisite Variety itself. (14:27)

Our present lack of a viable system management paradigm, or unifying theory of management, and the resultant threat to organizational viability, has pervaded the Department of Defense as well, threatening the viability of our defense system; numerous books and articles, describing all manner of defense acquisition system failings and proposed fixes, today stand testament to this fact.

To assess variation in the pursuit of stability, Acquisition Managers in the Department of Defense (DOD) have a fundamental requirement to monitor contractor performance; more precisely, to monitor and assess variation in the key elements of contractor performance and to control or influence, through interaction with the contractor, key variances. Entire disciplines, such as Cost/Schedule Control Systems Criteria (C/SCSC), designed to monitor contractor program cost and schedule variances, are devoted to the monitoring of key variances in contractor performance. Achieving and maintaining systemic stability must therefore be a joint, cooperative effort between contractor and program

office management. Precisely how the DOD and the contractor choose to identify and control variations in contractor system performance is critical; the wrong choices or the wrong control methods, or both, will guarantee a non-viable system, manifested in the failure of the DOD to provide for the real defense needs of our nation -- threatening the viability of both the DOD and the nation as a whole. Stafford Beer's Viable System Model (VSM) suggests that the defense contractor and the DOD have a mutual obligation to ensure the viability of one another. Both sides are currently failing in this obligation.

Measurement. The three widely-recognized determinants of contractor performance, within the DOD and the defense industry, are cost, schedule and technical performance. As the field of program management evolves, and the complexity of weapon systems increases, new techniques for measuring and monitoring variances within these three determinants of contractor performance are developed by the DOD in response to perceived inadequacies in present techniques, either those developed by the contractor or by the DOD. Subsumed in the cost and schedule elements is manufacturing labor, presumably a prime determinant of cost and schedule performance.

Any technique which management employs to gather data on process variation and assess common- and special-cause variation for stability, must be capable of (13):

1) providing sufficient data through time to generate statistically-verifiable standards, or control limits, for process performance against which subsequent performance data can be compared (note the emphasis on the natural evolution, rather than apriori selection of, a standard or control limit);

2) gathering representative performance data through time free of systematic error (i.e., bias), under controllable, repeatable conditions, which allow valid statistical variance analysis by comparison of in-process data with the standard or control limits; and

3) ". . . [directly measuring] the stability and instability in the system that [management] has subjectively defined." (8:287)

Further, the measurement itself must have requisite variety to absorb the variety of that which it claims to measure (8:281). Ashby's Law of Requisite Variety, a cornerstone of Beer's VSM, states that only variety can absorb variety (7:26), where variety refers to the total number of states that a system might attain (8:32, 7:21). A critical property of any measurement therefore is that it must be capable of specifying, without ambiguity, the state of the system being measured.

The basic components of, or prerequisites for, any viable system or organization are illustrated below in Figure

1. Every system has a purpose, or vision, defining its reason for existence.

VIABILITY

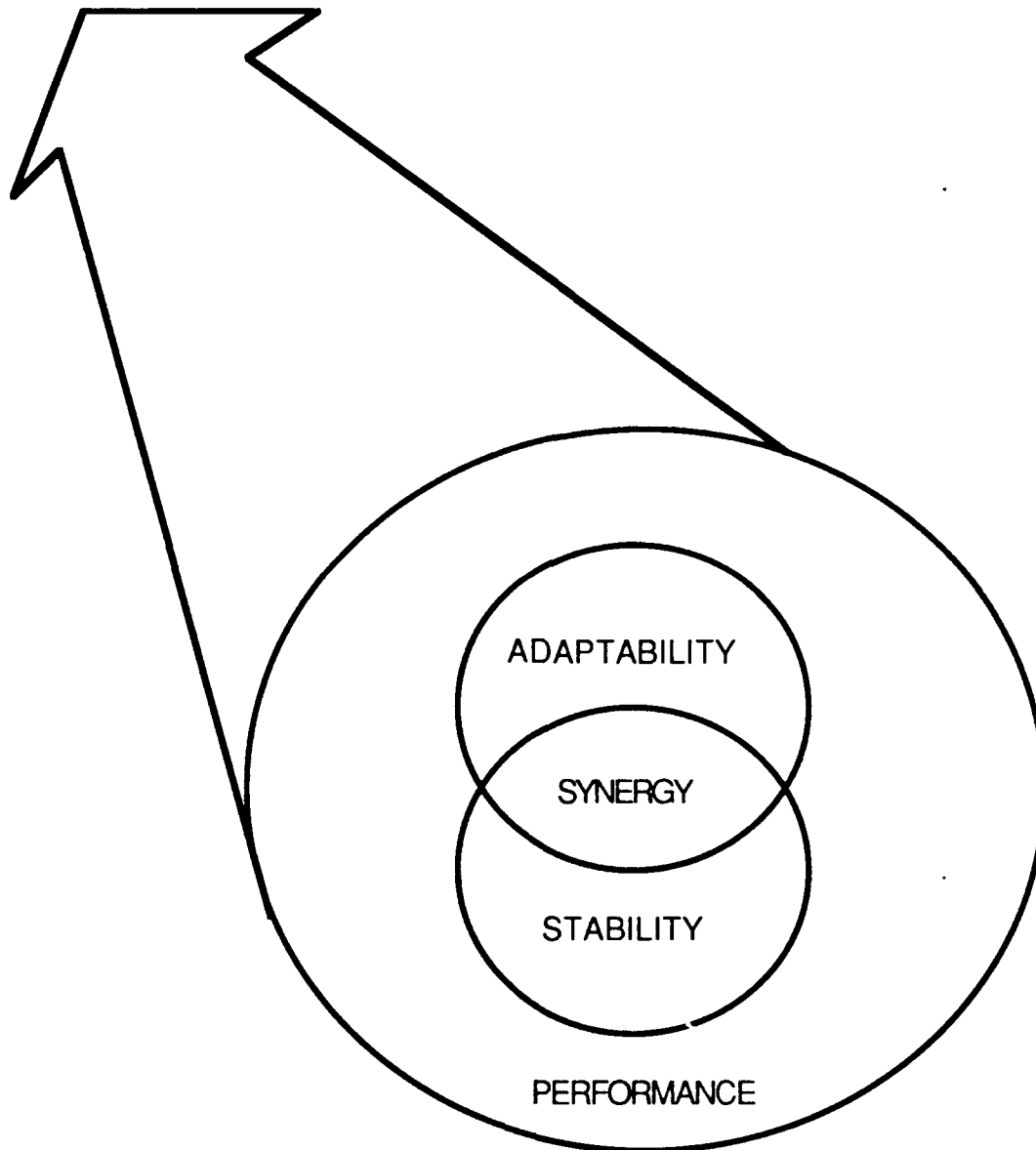


Figure 1. Basic Components of the Viable System

Typically, this purpose is oriented toward some form of output or productivity manifested in one, or a collection of, producing units or subsidiaries subsumed within the viable system. To attain its purpose, the system requires dedicated functions for both adaptability and stability, and a mechanism for synergy between these two functions. Stafford Beer refines these general criteria of the viable system into a formal Viable system Model which will be discussed in Chapter Two. The stability function of the viable system, defined by Beer as anti-oscillatory, must employ a continuous feedback and control mechanism. In summary, the salient requirements for systemic variance analysis and control to achieve stability are statistically-reliable and verifiable system standards or control limits, process data integrity, continuous feedback for effective control, and a measurement which directly indicates systemic stability and instability.

The Management Question. Traditionally, a management question facing Air Force Systems Command (AFSC) has been how to best monitor variation in the manufacturing-labor element of contractor performance and insure that the most effective and efficient methods are employed by the defense industry in building weapon systems for the Air Force. In short, the aim has been, and is, to achieve stability in the process which produces weapon systems for the Air Force as a necessary condition for the continued viability of our national defense system. Parallel to the industrial labor standards techniques

employed in non-defense industries, a Congressionally-mandated, DOD-developed technique for measurement of variation and control of manufacturing labor in the defense industry is MIL-STD-1567, Work Measurement.

MIL-STD-1567A states, "Experience has shown that excess manpower and lost time can be identified, reduced, and continued method improvement made regularly where work measurement programs have been implemented and conscientiously pursued" (22:iii).

Also, according to Karger and Bayha:

The work measurement engineer's output is used to establish as a standard the method and time required to perform a work task. In work measurement, standards are method and time solutions to work design problems, often of a unique or non-repetitive nature. Standards generally are established to record the resolution of such problems; but they also have an active aspect of facilitating the operating measurement of work and providing a basis for applying corrective control action when deviation is detected. (19:4)

Further,

Work Measurement offers one of the most reliable ways to achieve the benefits of increased production at a lower cost for the advantage of everyone. (19:11)

A far more critical management question for AFSC, in light of the VSM and the process phenomena of statistical fluctuation coupled with dependent events (as described in Goldratt's TOC), is whether the measurement and control of contractor manufacturing labor, in accordance with the precepts of MIL-STD- 1567, is necessary in the interest of

system optimization and maintaining the viability of the defense industry or whether it may instead be counterproductive. To answer this question, a cybernetic analysis of the application of MIL-STD-1567 to weapon systems acquisition management is necessary. Such an analysis will discover whether or not MIL-STD-1567 assists in, or detracts from, defense acquisition management efforts to ensure the viability of our defense system -- specifically, that part of our defense system which produces weapon systems for the USAF.

B. Specific Problem

Goldratt defines a core problem as a problem that "...has been in existence within our environment for many months or even years.... This provides us with the best indication that the perceived solutions are insufficient, otherwise the core problem would have already been solved." (18:36) Devising a measurement for program management indicative of defense acquisition program viability at the contractor level, and suitable for reporting within the DOD chain, is a core problem within the defense- industrial system. Perceived solutions to this core problem, of which MIL-STD-1567 is one such solution, are insufficient as indicated by the continuation of the core problem and the surrounding conflict.

Work Measurement has been a center of controversy throughout the defense industry and within the DOD since AFSC first released MIL-STD-1567 on 30 Jun 1975. The push by AFSC for defense contractor compliance with the provisions of MIL-STD-1567, and the use of labor standards to price and negotiate defense procurement contracts, has met with continued resistance within various levels of both the DOD and the industrial sector. Arguments continue throughout the defense-industrial complex over the need for, and benefits of, MIL-STD-1567A since direct labor is, by nature, the most controllable and therefore the most measured of the contract cost elements already. Indeed, countless articles and textbooks have been written on the how-tos of measuring and controlling manufacturing labor. And, as Goldratt would remind us,

A feature that will attract the interests of those motivated by the academic measurement of publish or perish . . . is a precisely defined problem. In such a case, people will certainly be more attracted to deal with a problem which is clearly defined, rather than with the more important problems which are vaguely stated.
(18:40)

In addition, the trend toward automation continues to reduce the level of direct labor in defense contracts, making the perceived benefits of precise measurement of the labor element (a local optima) continually smaller in comparison to the systemic perspective.

Although the 1986 DOD Authorization Bill (Section 917 of Pub. L. 99-145, 10 USC 2406) mandates standard labor hour reporting by defense contractors, the House Armed Services Committee (HASC) Counsel for Procurement Policy has called for repeal of this statutory requirement on the grounds that such standards are of questionable value in determining true contractor efficiency (23:22). Ms Ellen Brown, who is a regulatory affairs lawyer with the U.S. Chamber of Commerce, quantifies the cost aspect of the controversy by stating in an August 1986 Wall Street Journal article, "the law would be laughable were it not so expensive. In testimony before the HASC [House Armed Services Committee] earlier this year [1986], representatives of industry and the DOD estimated that the new law in the first year would cost up to \$30 million per company. The total cost could easily exceed \$1 billion" (10).

The Research Question. Presuming MIL-STD-1567 is a means toward achieving effective and efficient manufacturing labor methods (i.e. reduction in variation to attain stability), based on widely recognized labor standards techniques in the non-defense industries, the research question then becomes: why does such widespread controversy over Work Measurement continue within the defense-industrial complex? Can this continued controversy revolve around a heretofore un verbalized problem implicit in Work Measurement: is MIL-STD- 1567 a suboptimization technique which may

prevent management from pursuit of organizational viability through global optimization?

C. Research Hypotheses

R. Buckminster Fuller defines the basic synergetic system as a three-dimensional tetrahedron (16). Each vertex of the tetrahedron denotes a systemic event which interacts with each other vertex (event) simultaneously, in synergistic fashion, to define the output state of the system. To address the research question, four systemic qualities of the defense industry will be postulated as events which synergistically interact to form a systemic barrier to resolution of the measurement issue within the defense industry as illustrated in Figure 2. These events will be investigated as they relate to the use of labor standards in the manufacture of weapon systems. The four events are: the inherent lack of stability in the weapons procurement process, especially the instability generated by the DOD within the contractor's problematic environment; the failure of the government to establish and maintain a viable market for defense products; the dynamic tradeoff between regulation and variety amplification of the defense contractor's management system as manifested in the government's limitations of the autonomy of the contractor; and the use of cost, especially manufacturing labor cost, as a primary

measure of contractor performance in assessing program stability and achieving a viable defense-industrial system.

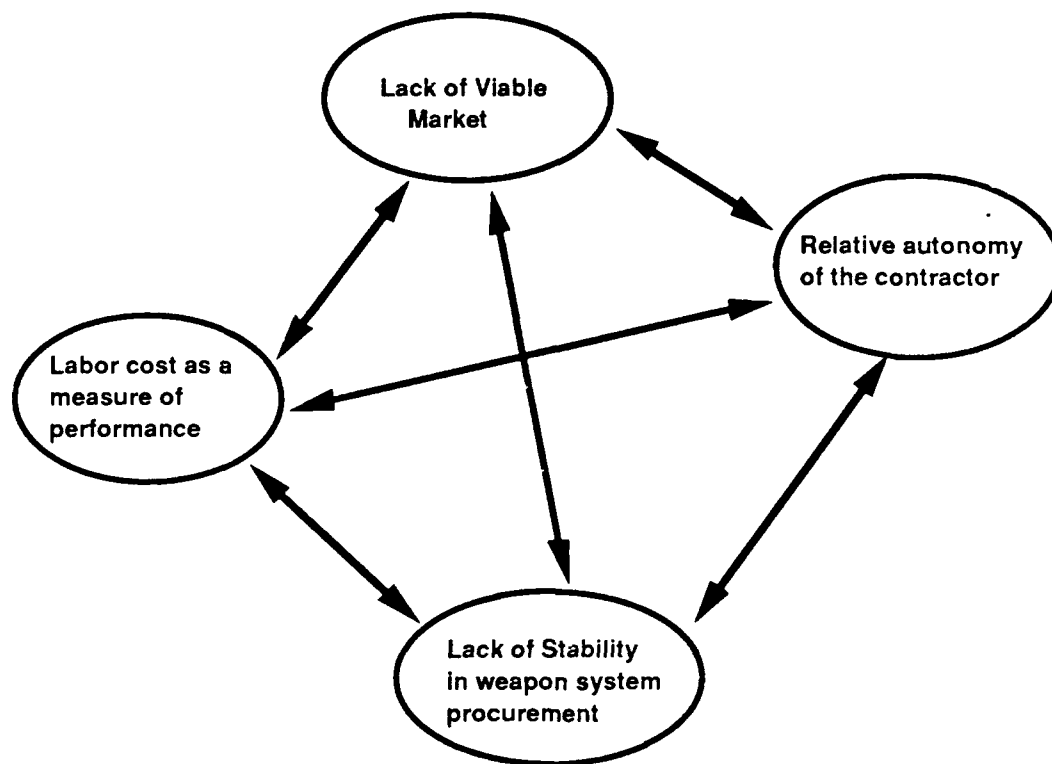


Figure 2. Systemic Barrier to Resolution of Measurement Issue

The existence of such a systemic barrier prevents the development of a measurement schema indicative of program stability and thereby prevents management from ensuring a viable system by interfering with the function of the antioscillatory component of the viable system. Without proper measurement of systemic performance, management can neither detect instability nor accomplish proper planning for

ongoing operations, also called tactical planning by Beer (p.167-180). As such, the activity of measurement occurs at the level of system operations and is subsumed within the antioscillatory function of the viable system. As shown in Figure 3 therefore, the hypothetical events described above (and shown in Figure 2) interact on the lower recursive level of the producing units to effectively prevent program stability and tactical planning, thereby negating the stability prerequisite of the viable system and destroying the synergetic interaction among the remaining components. Viability, the global goal and a result of the synergistic interaction among the viable-system components, has a direct tie to, and dependence on, each of these four events which were used to postulate the following four research hypotheses:

1. The inherent lack of stability in the weapons procurement process (e.g., systemic instability in the budget process, changing technical requirements and Congressional reluctance toward multi-year procurement strategies) generates a problematic environment for defense contractors of such high variety that neither DOD nor contractor management can achieve requisite variety, and thereby maintain viability, with the existing measurement schema.

2. The failure of the government to establish and maintain a viable market for defense products prevents contractor management from global optimization which, in

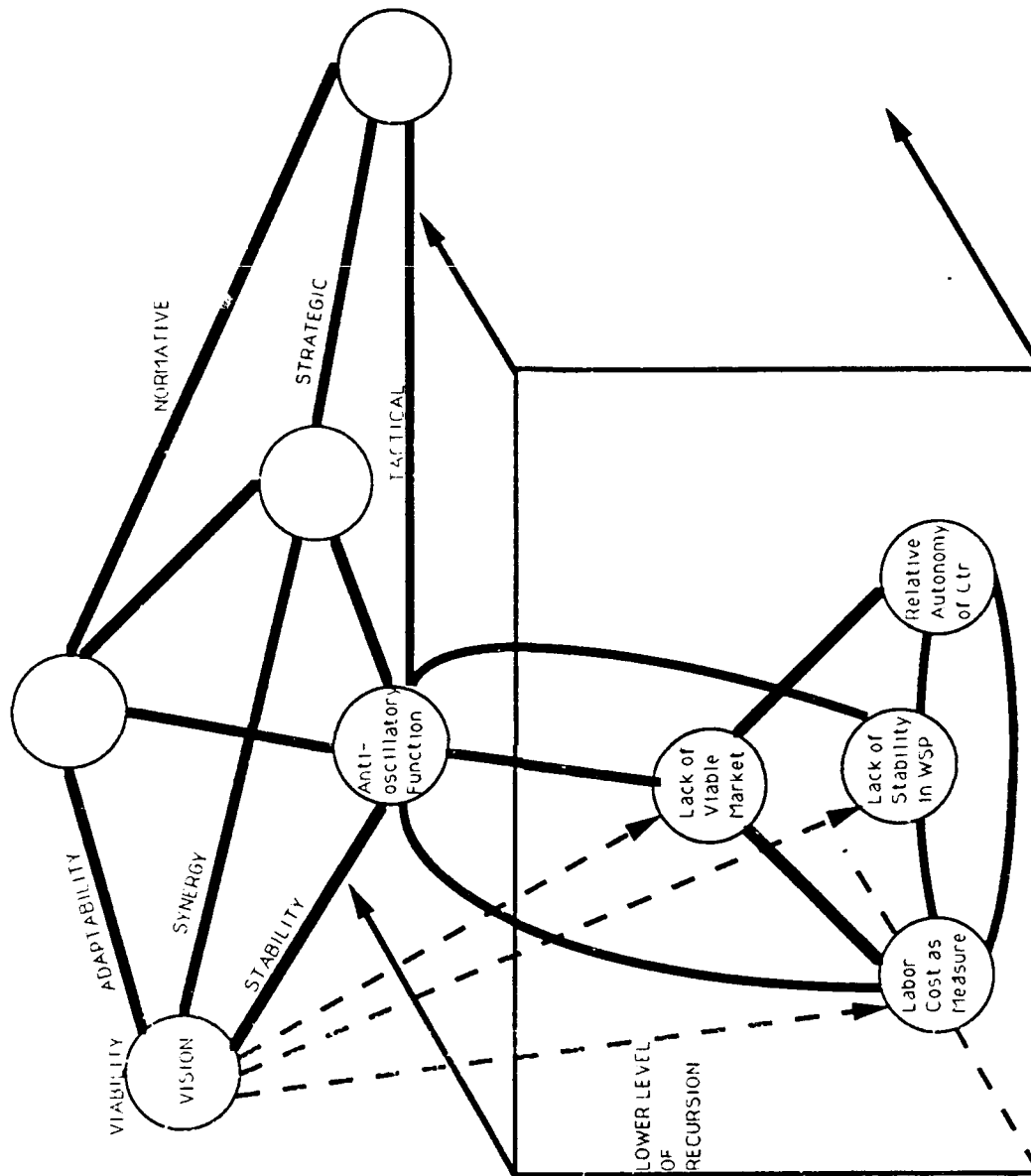


Figure 3. The Effect of Systemic Events on the Viable System

turn, has resulted in a proliferation of suboptimization management techniques and measurement schema, threatening the viability of the defense system.

3. The dynamic tradeoff between regulation and variety amplification of the defense contractor's management system must strike the correct balance between constraint and autonomy to achieve systemic stability. MIL-STD-1567 suboptimizes the contractor's management system, and thereby attenuates his requisite variety, to the extent that he can no longer achieve systemic stability.

4. Cost is not an appropriate measure of contractor performance; cost is, instead, a constraint to contractor performance. MIL-STD-1567, based on cost as a measure of performance, and concentrating only on the manufacturing labor element of cost, is a suboptimization technique which may prevent both DOD and contractor management from pursuit of systemic viability through global optimization.

D. Scope and Limitations

This research will concentrate on an analysis of the implications of MIL-STD-1567A, Work Measurement, for cybernetic management of aerospace weapon systems acquisition within the Aeronautical Systems Division (ASD) of Air Force Systems Command (AFSC). The cybernetic theory of Stafford Beer will guide the overall research and analysis.

This study will not attempt a cost/benefit analysis of the application of Work Measurement criteria to aerospace weapon systems procurement. Indeed, as Deming states regarding cost/benefit analyses:

The idea sounds good; catches on. But there are oftentimes serious difficulties. If you cannot estimate satisfactorily the numerator or the denominator of a fraction, it is impossible to calculate the value of a fraction. This is where cost/benefit analysis often leaves us. I would not participate in any attempt to use cost/benefit analysis for design of product where possible injury or loss of life is at risk. (13:395-396)

The overall goal of this research is therefore to theoretically assess the cybernetic value of MIL-STD-1567A in the management of aerospace weapons acquisition. Further, this thesis is intended as an inroad to the application of management cybernetics, as captured in Stafford Beer's VSM, to management pathologies within the DOD as a means of diagnosis and prescription. Work Measurement is only one small area wherein such pathology is apparent. Numerous other applications are both possible and required; indeed several other diagnoses are ongoing at the time of this writing.

II. Review of the Literature

A. Introduction

This Review of the Literature consists of three main parts: first, a discussion of the background and mechanics of Work Measurement, with emphasis on the specific requirements of MIL-STD-1567A, and the controversy surrounding Work Measurement; second, a review of Eliyahu M. Goldratt's Theory of Constraints; and third, a synopsis of managerial cybernetics, particularly Stafford Beer's Viable System Model. The intent in the order of this presentation of relevant literature is to make the reader familiar with the theoretical and practical background of the necessary topics as they will be addressed in the cybernetic diagnosis of Work Measurement contained in Chapter Four. Note that the terms "MIL-STD-1567," "MIL-STD-1567A," "Work Measurement (when capitalized)," and "MIL-STD" are used synonymously throughout.

B. Work Measurement

Work Measurement, in general, is a management philosophy with the underlying theme that "people's performance will improve if they know what is expected of them and receive frequent feedback on how they are doing. In short, set a standard and let people know what the standard is, and

productivity will increase" (20:31). According to Keyser and Meade, an effective work measurement system must provide feedback which has five requirements. The feedback must be frequent, immediate, specific, understandable, and positive (20:33). In general, regardless of the means for setting the work (or labor) standard, work measurement is a management style concentrating on open communication between worker and supervisor.

Present-day work measurement originated primarily from the work of Frederick Taylor and Frank Gilbreth during the industrial revolution in the United States. According to Karger and Bayha, "Frederick W. Taylor, generally known as the father of scientific management, was responsible for the first definitive approach to work measurement . . . [Taylor's guiding principle was that] the greatest production results when each worker is given a definite task to be performed in a definite time in a definite manner" (19:4-5). Similar work by the Gilbreths, Gantt, Emerson, and others pioneered the management practices, aimed at systematizing and standardizing the management of industry, which have come to be known as scientific management.

Summarizing Karger and Bayha's discussion of the origins of work measurement, a fundamental problem of industry in the late 19th and early part of the 20th century was the establishment of an adequate basis for measurement, indicative of productivity, necessary for effective

managerial control -- the same problem we are addressing today and further proof that this remains a core problem (19). Implicit in establishing an adequate basis for work measurement is the recognition that any work or time standard must be based on specific, recognized work methods so that methods improvement and work measurement go hand in hand. In fact, in the general case, work measurement is itself subsumed in the manufacturing methods, or industrial engineering, discipline. And, as Karger and Bayha note, "The interest in methods always is greatest during periods of low profit or severe competition" (19:1). Today we face both, worldwide.

Taylor's approach to work measurement was the Time Study. His stepwise description of the Time Study technique, performed in-plant, he developed is as follows:

1. Divide the work of a man performing any job into simple elementary movements.
2. Pick out all useless movements and discard them.
3. Study, one after another, just how each of several skilled workmen makes each elementary movement, and with the aid of a stopwatch select the quickest and best method of making each elementary movement known in the trade.
4. Describe, record, and index each elementary movement, with its proper time, so that it can be quickly found.
5. Study and record the percentage which must be added to the actual working time of a good workman to cover unavoidable delays, interruptions, and minor accidents, etc.

6. Study and record the percentage which must be added to cover the newness of a good workman to a job, the first few times that he does it. (This percentage is quite large on jobs made up of a large number of different elements composing a long sequence infrequently repeated. This factor grows smaller, however, as the work consists of a smaller number of different elements in a sequence that is more frequently repeated.)

7. Study and record the percentage of time that must be allowed for rest, and the intervals at which the rest must be taken, in order to offset physical fatigue.

8. Add together into various groups such combinations of elementary movements as are frequently used in the same sequence in the trade, and record and index these groups so that they can be readily found.

9. From these several records, it is comparatively easy to select the proper series of motions which should be used by a workman in making any popular article, and by summing the times of these movement and adding proper percentage allowances, to find the proper time for doing almost any class of work.

10. The analysis of a piece of work into its elements almost always reveals the fact that many of the conditions surrounding and accompanying the work are defective; for instance, that improper tools are used, that the machines used in connection with it need perfecting, that the sanitary conditions are bad, etc. And knowledge so obtained leads frequently to constructive work of a high order, to the standardization of tools and conditions, to the invention of superior methods and machines. (19:5-6)

Coincident with Taylor's development of the Time Study approach to work measurement, Mr. Frank B. Gilbreth, with the assistance of his wife, Dr. Lillian M. Gilbreth, began his own research in the field he called Motion Study which

involved laboratory analysis of work methods and motions and lead to a formal Micromotion Study procedure that is the basis of present work measurement predetermined time standards. According to Karger and Bayha,

Frank and Lillian Gilbreth refined Taylor's concept of work elements by further subdivision in therblig (their name spelled backwards) elements, which to them were basic manual work segments describing the human sensory-motor activities or other basic elements of an operation. Therbligs form a generally recognized basic language for methods description usable in expressing motion-time data. [Therbligs] . . . lead in a modified form to a classification of elements adequate for what is known today as predetermined time standards. (19:9)

In using predetermined time standards, the analyst selects basic-motion time values (basic body motions such as reach), for a precisely-defined larger task, from any of several compilations of basic-motion tables, or data bases, which have evolved over the years. The best-known of these published standard tables are those of the Methods-Time Measurement (MTM) Association (25:680). In fact, in a 1987 study of 22 commercially-available predetermined time systems, done for the United States Air Force (USAF) by Arthur Young and Company, the MTM-1 time system was used as a baseline for comparison and rating of each of the other time systems evaluated, including several other MTM systems. (2)

Schonberger and Knod list six basic techniques for setting time standards: stopwatch time study, work sampling, predetermined time standards, standard-data time standards,

historical standards, and technical estimates (25:689). Of these six, the last two (historical time standards and technical estimates) fall into the category of non-engineered labor standards, or, in MIL-STD-1567, Type II Standards. The first four are all Type I, or engineered Standards; stopwatch time study and work sampling falling under the general Time Study approach of Taylor; and predetermined time standards and standard-data time standards falling under the Motion Study approach of Gilbreth.

According to Schonberger and Knod, the use of Predetermined Time Standards (based on Motion Study) in deriving standard times for particular tasks is by far the most detailed, particularly the MTM technique.

Basic MTM motions are tiny; motions are measured in time measurement units (TMUs) and one TMU is only 0.0006 minutes [0.036 seconds]. A 1.0-minute cycle time equals 1,667 TMUs. One MTM motion usually takes 10 to 20 TMUs; thus, about 80 to 160 motions would be identified in the 1.0 minute period. To arrive at a standard time, the analyst enters each motion on a simultaneous motion (SIMO) chart, which is a left-and-right-hand chart. The total TMUs on the chart are converted to minutes. The total is the rated (leveled) time, not the cycle time, because 100 percent pace is built into the tables. Add a PR&D [personal rest and delay] allowance, and you have the standard time. (25:680)

Standard-data time standards or standard-data tables are also derived from Predetermined Time Standards and are typically industry-specific. Schonberger and Knod point to the example of a Flat-rate repair manual in the auto industry which might

list standard times for repair tasks like changing spark plugs (25:681).

The Time Study, as noted above, involves direct observation of a worker and timing the elements of a task after verifying that the worker is performing the task in accordance with the method prescribed by the analyst. In some studies, cameras or video recording devices are used to record the work for later analysis but usually the analyst performs the observation directly and uses a stopwatch to time the performance of the task elements. Time Study is generally preferred for short-cycle tasks due to the expense of an on-site analyst to observe and time numerous repetitions, or cycles, of the task. In fact,

. . . most firms pay more attention to the cost of multiple cycles than to the statistical dispersion of readings. For example, General Electric has established a guide to the number of cycles. The table calls for timing only 3 cycles if the cycle time is 40 minutes or more, but it calls for timing 200 cycles if the cycle time is as short as 0.1 minutes. (25:677- 678)

Average cycle time for the task is then leveled by multiplying by a pace rating, as subjectively determined by the analyst, to account for the relative speed of the worker who performed the task during the study. A pace rating of 100% is considered the "normal" working speed. According to Schonberger and Knod, "most [analysts] can become good enough at pace rating to be able to come within [plus or minus] 5% of the correct ratings on training films" (25:678). A

Personal Rest and Delay (PR&D) allowance is then added to the leveled time to arrive at the standard time for the task.

Standards can also be obtained through Work Sampling. In this case, the analyst randomly observes the worker, recording the time spent on various tasks, assigning a pace rating, and determining a production count. The cycle time is then determined as the product of the percent of time spent on a task and the total minutes in the study, divided by the production count. As in Time Study, the cycle time is leveled and a PR&D allowance added to arrive at the standard time for the task; in this case the standard time is for the production of one unit or output.

MIL-STD-1567 Requirements and Purpose. In the broadest sense, MIL-STD-1567 is meant to be a cost-cutting tool for the DOD. The purpose of MIL-STD-1567 (re-released on 11 Mar 1983 as MIL-STD-1567A) is to achieve cost savings in weapons procurement for the government by contractually prescribing touch-labor data collection and analysis methods which the contractor shall undertake to develop standard times for labor-intensive tasks. These standard times are then compared to actual hours to identify and remedy inefficiencies and/or used as a proposal basis for subsequent contract pricing and negotiation. As stated in the MIL-STD-1567A Foreword, the intent is to "assist in achieving increased discipline in contractor's work measurement programs with the objective of

improved productivity and efficiency in contractor industrial operations" (22).

The introductory portions of MIL-STD-1567A go on to state several "benefits which can accrue as a result of the employment of a work measurement program" (12). Among these are:

- 1) Achieving greater output from a given amount of resources;
- 2) Obtaining lower unit cost at all levels of production;
- 3) Reducing the amount of waste time in performing operations;
- 4) Reducing extra operations and the extra equipment needed to perform these operations;
- 5) Improving the budgeting process and providing a basis for price estimating;
- 6) Improving production control activities and delivery time estimation;
- 7) Focusing continual attention on cost reduction and cost control;
- 8) Helping in the solution of layout and materials handling problems by providing accurate figures for planning and [use] of such equipment;
- 9) Providing an objective and measured base from which management and labor can project piecework requirements, earnings, and performance incentives. (22:iii-iv)

How does use of MIL-STD-1567A achieve these ambitious goals?

Section one of the standard says that "It [MIL-STD-1567A] establishes criteria which must be met by the contractor's work measurement programs and provides guidance for implementation of these techniques and their use in assuring

cost effective development and production of systems and equipment" (22:1). Presumably then by adherence to the requirements of the MIL-STD, the contractor will achieve the manufacturing efficiency necessary to bring about such cost savings through lowering product unit labor costs. The MIL-STD defines both general and specific requirements which the contractor's work measurement system must meet.

Minimum general requirements of the contractor's work measurement system, which satisfy the contractual intent of Work Measurement, include the following:

- 1) An explicit definition of standard time that shall apply throughout the jurisdiction of the work measurement program;
 - 2) A work measurement plan and supporting procedures which describe the contractor's work measurement system and how lost and idle time and/or "unmeasured" work will be monitored and accounted for;
 - 3) A clear designation of the organization and personnel responsible for the execution of the [work measurement] system;
 - 4) A plan to establish and maintain engineered [Type I] labor standards to known accuracy;
 - 5) A plan to conduct methods engineering studies to improve operations and to upgrade Type II labor standards to Type I Engineered Labor Standards;
 - 6) A plan for the use of labor standards as input to budgeting, estimating, and production planning;
 - 7) A plan to ensure that system data is corrected when labor standards are [updated].
- (22:4)

Engineered labor standards, or standard labor hours (the two terms are synonymous in the MIL-STD), are developed and refined, at the operations level, by the contractor over time using one of five techniques: Time Studies, Work Sampling, Predetermined Time Systems, Standard Data, and Previous Experience. The three most common techniques are Time Studies, Work Sampling and Predetermined Time Systems (22:25). By definition in the MIL- STD, an operation is either: "a job or task consisting of one or more work elements, normally done essentially in one location; or the lowest level grouping of elemental times at which PF&D allowances are applied" (22:3). As described above, the methodology used for determining component times is what distinguishes one technique from another and is also what distinguishes the resulting Type I from Type II Standards.

The specific requirements of MIL-STD-1567A deal primarily with guidelines for contractor development and use of these engineered labor standards, which are the heart of Work Measurement. Two types of engineered labor standards are recognized by the MIL-STD: Type I (Engineered) Labor Standards and Type II (Non-Engineered) Labor Standards. The difference between these two types of standards lies both in the accuracy and confidence at the operation(s) level and the technique used to derive the standard time(s). Type I standards are required to reflect an accuracy of +/- 10% with a 90% confidence at the operation level and may be

established using recognized techniques such as Time Studies, Predetermined Time Systems, Standard Data, or a combination thereof, ". . . to derive at least 90% of the normal time associated with the labor effort covered by the standard Work Sampling may be used to supplement or as a check on other more definitive techniques" (22:4). Type I standards must also include:

- 1) Documentation of an operations analysis;
- 2) A record of standard practice or method followed when the standard was developed;
- 3) A record of rating or leveling;
- 4) A record of the standard time computation including allowances;
- 5) A record of observed or predetermined time system time values used in determining the final standard time. (22:4)

Type II standards are those not meeting the Type I criteria (22:4,16). The Previous Experience technique falls into the Type II category. Type II Standards provide work measurement coverage at program initiation. The contractor is required by the MIL-STD to develop a Work Measurement Touch Labor Coverage Plan which provides a schedule for upgrading Type II Standards to Type I standards to achieve 80% coverage of all categories of touch labor hours with Type I standards by the Production Phase of the program (22:5,21).

The key to achieving production cost savings then lies in the contractor's analysis of variances between actual or incurred labor hours and standard labor hours. Once the contractor has thoroughly analyzed these variances, he then formulates any necessary corrective action plan(s) to bring actual performance in line with the standard, presumably eliminating inefficiency and lowering manufacturing costs. Predetermined variance thresholds, as related to labor-performance goals, are established to trigger variance analyses. Consistently high variances may identify operations for method improvement study to reduce labor content, search for special-causes of variation which degrade product quality, or eliminate production bottlenecks.

Periodic review and audit by the government is intended to ensure follow-through on corrective action plans. To this end, the MIL-STD requires that the contractor perform a self-audit of his work measurement system at least annually and retain a copy of the audit report for at least two years. The contractor shall make these audit reports available to the government upon request (22:7).

Specifically, MIL-STD-1567 requires the contractor, as part of his work measurement program, to generate and analyze labor performance reports for each work center no less often than weekly. These performance reports are to be summarized at each appropriate management level and indicate labor efficiency, comparing current results with pre-established

goals (22:6). Supervisory and staff support personnel are to review the labor performance reports and prepare a formal written analysis, which addresses causes and corrective actions, whenever a significant variance is noted between current performance and pre-established labor performance goals. Labor performance is assessed via one of two measures: Labor Efficiency or Realization Factor.

Labor Efficiency is the ratio of Earned Hours to Actual Hours, which, per the MIL-STD, is "a measure of operator efficiency [or the efficiency of a group of operators] against a particular task or aggregation of tasks" (22:14). Actual Hours generally exclude charges for unmeasured work, idle or lost time beyond the control of the worker, and scrap/rework due to vendor material defects; scrap/rework due to worker error is included. Earned Hours are standard hours credited to a worker based on completion of a task or operation as expressed in work units of either end items, operations, or lots/batches of end items. Partial credit for work completion is also allowed.

The aggregate measure of labor performance for the shop, product line, or plant is the Realization Factor which is the ratio of Total Actual Hours to Total Earned Hours. Elements of the Realization Factor are used to describe and analyze the learning curve effect and product technical and manufacturing logistics considerations and may be used to modify Touch Labor Standards (standard times) for purposes of

planning, budgeting, scheduling, or estimating (22:16). Only unmodified labor standards are used in evaluating labor performance, however. Individual program characteristics, such as product complexity, design stability, and manufacturing process maturity, determine the relative importance of each element of the Realization Factor (22:23).

The Controversy Surrounding Work Measurement. Since the United States Air Force (USAF) first released Military Standard (MIL-STD) 1567 (Work Measurement) on 30 Jun 1975, this standard has been a center of controversy. Now, over fifteen years later, this controversy is still largely unresolved. Even though reporting of standard labor hours by defense contractors was mandated by Congress in the 1986 Department of Defense (DOD) Authorization Bill, implementation of Work Measurement by the military has remained sluggish and the aerospace defense contractors have continued to resist Work Measurement as they did from the outset.

Although the problems associated with implementation of Work Measurement and its controversial nature are well documented in the literature, discussions of possible solutions are scarce to nonexistent. The USAF stereotypes the issues as contractor footdragging while contractors generally see Work Measurement as a costly, meddlesome system foisted upon them by the government. This section first expands on the regulatory environment and labor relations

problem created for contractors by Work Measurement. Then the controversy from both the DOD and contractor perspectives, as reported in the literature, is discussed.

Implementation of a work measurement program on government procurement contracts is mandated in USAF procurement regulations, HQ AFSC policy memoranda, and Public Law. The 800- series of USAF regulations (the procurement regulations) require that the acquisition strategy and contract comply with, or incorporate, the provisions of all applicable MIL-STDs. Work Measurement is applicable to all full-scale acquisition program developments which exceed \$100M and all new or follow-on acquisition contracts which exceed \$20M annually or \$100M cumulatively, excluding Military Construction (MILCON) Programs (MCP), based upon program dollar value (not individual contract value) as reported in the Five Year Defense Plan (FYDP) (22:1). AFSC policy requires the use of work measurement data, when available, in contract pricing (21:2). The MIL-STD was given quasi-legal status in November, 1985, when the 99th Congress enacted Public Law (P.L.) 99-145, The Fiscal Year 1986 DOD Authorization Act. Title IX, Section 917 of P.L. 99-145 (Cost and Price Management in Defense Procurement) states that "Each contractor preparing a bill of labor [for a defense contract proposal] shall specify in the bill of labor the current industrial engineering standard hours of work

content (also known as 'should-take times') . . ."

(27:99STAT.689) .

Work measurement standards (or labor standards), by their nature, may become a cause for labor disputes between the contractor and his work force. Industrial Engineers, specializing in work measurement, are frequently called upon by companies to represent management in disciplinary cases, based upon worker digression from the standards, which go before regulatory boards, union panels, or arbitrators. In some cases, highly-specialized work measurement consultants are brought in to represent the corporation along with the corporate lawyer(s). According to Snyder, in his article "IEs Must Convince Arbitrators That Work Measurement Data Are Fair and Accurate", "The industrial engineer presenting the data must convince the party [board, panel, or arbitrator] that the measurement program was designed properly, with attention to detail, that the daily data were collected and tabulated accurately, and that the interpretation of the results were done professionally and without prejudice." Snyder goes on to say that union panels frequently challenge both the credentials of the industrial engineer and the approach or design of the work measurement system itself. Questions are frequently asked relating to the company's ability to prove that all pieces of equipment perform at the same rate, whether or not the data take seasonal variation into account, what the statistical measure of error and standard deviation

is, and the length of accuracy for the data in question. (26:29-32) With this ever-present added burden of proof on the company brought about by organized labor, work measurement systems require extreme diligence and considerable investment. These complications contribute to contractor resistance toward MIL-STD-1567, fueling the controversy.

This controversy over Work Measurement generally falls into one of two categories: the political argument and the cost-benefit argument. One might add that the separation between these two arguments is not often distinct. Furthermore, the issue is not merely one of government versus contractor since both sides have their proponents and opponents of Work Measurement.

The initial arguments, raised by the defense industry, against MIL-STD-1567 were largely political and viewed by some in the government as purely emotional (1:7). From the defense industry viewpoint, "The question [was] not the adequacy of the proposed MIL-STD-1567, the question [was] whether any customer, including the Government, has a right to coerce private industry by a system of checks and balances on their management practices" (11:14). The DOD rejoinder was that "DOD policy and sound management theory dictate a minimum of paper work and interference with the contractor's operations." Indeed the government believed (and still believes) that the introduction of a Work Measurement

standard should have little impact on contractor business practices since "virtually all of [the DOD] contractors already have some type of work standard programs [in place]. . . ." (11:22) As such, the government views MIL-STD- 1567 as merely a means of assuring some least common denominator in how work measurement is implemented and used across the industry.

As reported in the November 1976 issue of Industrial Engineering,

"Even before the document [MIL-STD-1567] was officially released . . . questions concerning how it should be implemented, and, perhaps more importantly, should it be implemented, were being raised by the people ultimately responsible for work measurement - industrial engineers. Industry representatives [were] divided amid a spectrum of cries ranging from 'deterrent to free enterprise,' 'galloping socialism,' and 'cost-prohibitive administrative monster,' on one side, and 'long overdue,' 'badly needed-necessary and acceptable,' on the other" (11:14)

Government sentiment has also ranged from strong support from Headquarters Air Force Systems Command (AFSC), who originated MIL-STD-1567, to calls for repeal of the statutory requirement for contractors to report on standard labor hours (Sec 917, P.L. 99-145) by the counsel for procurement policy, House Armed Services Committee (HASC) (23:22).

The former Director of Manufacturing for Air Force Systems Command (AFSC), Col Roger Alexander, proposes that the reason behind the contractor resistance was, and continues to be, that "contractors resist anything that will

reduce their profitability." He states that since government procurement regulations dictate that profit will be computed as a percentage of cost, anything that is done to reduce cost results in a reduction in profit and will therefore meet resistance from the defense industry. (1:9)

According to Col Alexander's report, during a two-day conference hosted by AFSC in February 1985, industry spokesmen voiced three main reasons why the defense industry believes that DOD emphasis of MIL-STD-1567 is inappropriate. The first of these is that direct labor (i.e. manufacturing labor) is a small percent of the overall cost of production and is growing smaller through the increased use of automation. Second, direct labor is already the most measured of the cost elements [probably since direct labor is the most controllable of any of the cost elements]. Third, other cost reduction initiatives and techniques show far greater potential for overall cost reduction [e.g. low-risk transition to production, Technology Modernization -- the so-called TECHMOD program, producibility engineering and planning, etc.]. Further, industry spokesmen reiterated their position that the requirements of MIL-STD-1567 were unnecessary and burdensome since most contractors already have a work measurement program in place. AFSC acknowledged these points and responded by stating that the main concern of government was that the contractor work measurement

systems in place were not as effective as they could be.

(1:7,8)

A paradox emerges from consideration of the industry position, stated above, and the DOD acquisition and contracting environment dictated in part by the DOD budget process. The paradox is this: the use of a labor standard rests implicitly on the assumption of a certain stability in production - but production of weapon systems, by the nature of the acquisition and budget process, rarely, if ever, achieves stability. In fact, the general assumption in the defense industry is that stability is generally attained at the 1000th production unit (21:9). Lot quantities are traditionally small, rarely, if ever, reaching 1000 units, and the planning horizon is short. Multiyear procurement, which may enable greater planning and production stability, is often discouraged by Congress since multiyear budget authority reduces the amount of relatively controllable outlays managed by Congress (12). So the political debate continues but the lasting questions over MIL-STD-1567 go beyond politics.

The overriding question for MIL-STD-1567 on both sides has been one of cost versus benefit. To date, no one has been able to quantify and substantiate either the implementation costs or the benefits of a defense industry-wide Work Measurement standard, although several have tried. This results from many factors, among which are the slow pace

of implementation of MIL- STD-1567A on USAF contracts; lack of agreement and intent among the services where MIL-STD-1567A requirements are concerned (e.g. the Army recognizes no requirement for including MIL-STD-1567A in any procurement contracts); and the widely differing states (maturity and methods) of existing, "in-house" systems at the contractor facilities. A 1987 Air Force Institute of Technology (AFIT) thesis concluded that "an objective examination of the costs versus the benefits of MIL-STD-1567A . . . should be conducted after further implementation by all services" (21:83).

Several attempts at cost-benefit analyses for MIL-STD-1567 have, in fact, been made. The results and conclusions vary dramatically. Col Alexander discusses a 1980 Government Accounting Office (GAO) report which cited several examples of dramatic cost savings at contractor facilities where MIL-STD-1567 was employed. In one instance, the Air Force was reported to estimate savings at Boeing Aerospace Company of approximately \$31.3 million with an investment of only \$1.8 million in the implementation of Work Measurement. The GAO report also stated that "where implemented by the Air Force, anticipated problems by industry, DOD and all services in getting the MIL-STD on contract have not surfaced . . . [and] that contractors apparently have proposed no visible costs to the contractual requirements of the MIL-STD." (1:6-7)

This is in sharp contrast to an article written by Ms Ellen Brown, who is a regulatory affairs lawyer with the U.S. Chamber of Commerce. Ms Brown's article, which appeared in the 5 Aug 1986 edition of the Wall Street Journal, addresses the standard labor hour reporting requirement in P.L. 99-145 and says that "the law would be laughable were it not so expensive. In testimony before the HASC earlier this year, representatives of industry and the DOD estimated the new law in the first year would cost up to \$30 million per company. The total cost could easily exceed \$1 billion. The cost to maintain the system in subsequent years will be only slightly less" (10). These staggering costs are, by far, the greatest strike against MIL-STD-1567 in this era of the declining defense budget.

After 15 years, the controversy over MIL-STD-1567 continues with no sign of letup. Few would argue against the basic premise of Work Measurement. Indeed "it would be folly for management to attempt to manage without some knowledge of the most efficient and effective manufacturing methods" (28:1). Yet the political arguments over the fairness of the MIL-STD and details of its implementation, the potential for added complication brought on through labor disputes, and the unanswered questions concerning cost and benefit all stand in the way of resolving the controversy. As yet, the services have no unified position for implementation across the defense industry. Without such a unified stance, the cost-

benefit question may never be fully answered. For MIL-STD-1567, the sheer magnitude of the implementation cost may well prove its downfall.

C. The Theory of Constraints

Eliyahu M. Goldratt's Theory of Constraints is a management philosophy aimed at creating an environment within the organization conducive to perpetual change and improvement from the global perspective through focusing on systemic constraints and the change process itself. This section of the Literature Review will discuss the highlights of the Theory of Constraints, Goldratt's three measures, necessary and sufficient for the management of any operation, Throughput, Inventory, and Operational Expense, as developed in The Goal (17), and the concepts of process bottlenecks and dependent events coupled with statistical fluctuations.

Goldratt summarizes his Theory of Constraints as a two-part problem-solving technique. First, "using the terminology of the system to be improved," management must focus on, and accomplish the following in a never-ending cycle:

1. Identify the system's constraints.
2. Decide how to exploit the system's constraints.
3. Subordinate everything else to the above decision.

4. Elevate the system's constraints.

5. If in the previous step a constraint is broken, go back to Step 1, but do not allow inertia to cause a system constraint. (18:75)

Commensurate with the focus on the system's constraints, the second part of the Theory of Constraints deals directly with the improvement process itself. According to Goldratt, "using the terminology of the improvement process itself," management must focus on three areas: 1) Deciding what to change by pinpointing core problems through the use of the Effect-Cause-Effect method; 2) Deciding what to change to by constructing simple, practical solutions through the use of the Evaporating Clouds method; 3) Causing the change by inducing the appropriate people to invent solutions through the use of the Socratic Method. (18:76)

In Goldratt's Theory of Constraints, and also in Stafford Beer's management cybernetic theory, discussed in the next section, the notion of any system is meaningless without a definition of the systemic purpose or goal. According to Goldratt, "The first step is to recognize that every system was built for a purpose This immediately implies that, before we can deal with the improvement of any section of a system, we must first define the system's global goal; and the measurements that will enable us to judge the impact of any subsystem and any local decision on this global goal" (18:4). Having defined the system's global goal, we

can then identify the system's constraint(s): "A system's constraint is . . . anything that limits a system from achieving higher performance versus its goal" (18:4).

According to Goldratt, there is only one goal, no matter what the company. Productivity, like the system itself, is again meaningless unless the goal is defined. Once the global, or systemic, goal has been defined, productivity is then seen as either "accomplishing something in terms of your goal" or "the act of bringing a company closer to its goal" (17:32). A major part of Goldratt's critique of our current management philosophy is that most companies pursue efficiency goals for each operation within the overall system, presumably to cut cost and therefore increase profit, as though high efficiency was the global goal. This is, in Goldratt's terminology, suboptimization -- also referred to as local optimization. Further, as illustrated in *The Goal*, concentrating on efficiencies of each local operation will likely result in high levels of inventory, high amounts of work in process, delays in delivery and cost overages -- in short, a highly inefficient system.

Goldratt's contention is that every company has but one global goal: to make money. His work has proven that "current measurements used on the shop floor are a major stumbling block to improvement (17:v)" principally because they are not defined in terms of the goal. Indeed, Goldratt's attack on management orthodoxy has centered on

Cost Accounting practices, something he calls "enemy number one of productivity" (17:v). The plethora of measurements developed for all of the various levels of management and departments are worthless because they tell management nothing about how to improve. The measurements are too specialized and fail to mesh into a coherent picture of how productive the company truly is in terms of its goal. In short, orthodox measurements fail to capture anything of the true organizational productivity and concentrate instead on local, or departmental optimization to the detriment of the organization as a whole, providing management with no basis for action in the interest of continual improvement.

Goldratt's remedy, where measurement is concerned, is to introduce three measures, necessary and sufficient in the management of any organization, defined in terms of the global goal of making money: Throughput, Inventory, and Operational Expense. Goldratt defines each of these three measures as follows:

1. Throughput is the rate at which the system generates money through sales [Note that this is not the rate at which the system produces a product according to the conventional definition of throughput of raw materials and conversion into finished goods. You don't make money by producing, you make money by selling].

2. Inventory is all the money that the system has invested in purchasing things which it intends to sell.

3. Operational Expense is all the money that the system spends to turn inventory into throughput. (17:59-60)

These three measures are grounded in orthodoxy but arise from three generic, fundamental measures which must be present somewhere in every measurement schema concerned with the management of an enterprise. First, there must exist an absolute measurement, Net Profit. Second, there must exist a relative measurement, Return on Investment (a comparison of money made to money invested). Third, there must exist a measure of cash flow; without cash flow, you haven't the necessary condition for staying in business.

Goldratt then evolves these generic, fundamental measures into Throughput, Inventory, and Operational Expense in recognition of the shortcomings of conventional measurements which do not lend themselves to the daily operation of the manufacturing organization (17:59). The global goal is then restated in terms of the measurements as follows: "Increase throughput while simultaneously reducing both inventory and operating expense" (17:66). Now the measurements are cast in the language of daily operations and inform management directly of the state of the system relative to the global goal of making money. Further, the measurements suggest directly and immediately any necessary actions on the part of management to remedy situations which cause the organization to deviate from its goal.

The notion of throughput presumes a viable market in which the firm can operate; the type of market which the DOD

is failing to provide our defense contractors, as discussed further in Chapter Four. Orthodox management dictums state that managers should strive to balance plant capacity with market demand, the exact capacity-planning strategy dictated by the type of business (e.g., make to stock, make to order, etc.). In contrast, Goldratt maintains that "you should not balance capacity with demand [instead you should] balance the flow of product through the plant with demand from the market" (17:138). And the flow of product through the plant is dependent upon the capacity of the production bottleneck(s).

In manufacturing operations, the system constraint(s) are the production bottleneck(s), defined as any resources whose capacity is equal to or less than the demand placed on it. Further, "we cannot measure the capacity of a resource in isolation." (17:136-138) Production bottlenecks determine the effective capacity of the plant. What the manager must then strive to do, according to Goldratt, is to make the flow of product through the bottleneck(s) equal to, or slightly less than, market demand. Thus the firm may only realize its goal once it determines demand from a viable market and then manages to equate bottleneck throughput with this demand while simultaneously reducing inventory and operating expense.

Dependent events and statistical fluctuations, two phenomena found in every plant, operation, or process, make

the balancing of bottleneck throughput with demand a necessity and the orthodox notion of balancing capacity with demand a sure road to bankruptcy (17:85-87). Local optimization strategies, espoused in orthodoxy, implicitly assume that each operation within the producing system is an independent event; further, that statistical fluctuations within individual operations average, or "cancel" each other out. Given these assumptions, the orthodoxy logically concludes that by ensuring maximum efficiency of each operation, the entire system is guaranteed optimal operation. Throughout The Goal, Goldratt addresses this fallacy.

Any sequence of operations, whether composed of major activities on a production line or viewed as the series of motions made by an individual worker in the completion of a given task, is comprised of dependent events if the completion of a subsequent activity or motion depends upon the completion of a preceding activity or motion. The distinction between independent and dependent events has decidedly serious consequences in the management of systems for production. Because, as Goldratt states, ". . . in a linear dependency of two or more variables [or events], the fluctuations of the variables down the line will fluctuate around the maximum deviation established by any preceding variables [so that] the maximum deviation of a preceding operation will become the starting point of a subsequent operation" (17:112,133). In short, statistical fluctuations

in processes are additive in a system comprised of dependent events.

Because of this additive property of statistical fluctuation, Goldratt contends that we can never measure the capacity of a resource in isolation (17:133) which is precisely what the orthodox measurement and rating schema do. The result is a propensity to focus on the efficiencies of each individual operation or use of each resource category -- the relevant concern in work measurement being labor, or worker efficiency. An analysis of the implications of the Theory of Constraints where labor efficiency and work measurement is concerned will be taken up in Chapter Four.

D. Management Cybernetics and The Viable System Model

The opening sentence in Chapter One stated that management's charge is to create an organizational structure and environment which allows the organization to achieve and maintain viability. As noted earlier, numerous suboptimal management theories have been advanced which fail to address organizational viability as the charter of management, much less how to manage in pursuit of viability. A unifying, systemic management paradigm to guide managers in securing viability for their organization is the central topic of the works of Stafford Beer, anchored in the theories of cybernetics. This section of the Literature Review will

discuss the highlights of Stafford Beer's Viable System Model (VSM), as embellished by Raul Espejo, with particular emphasis on the implications of the VSM and cybernetics for the development of measurements necessary for the control of operations. Basic concepts and definitions necessary in the development of the VSM will first be addressed, followed by a description of the VSM itself and the diagnostic tools it offers for the manager; finally, the design of cybernetic measurement and filtration systems for controlling operations will be discussed. The VSM and these cybernetic measurement and filtration systems are at the heart of the cybernetic analysis of work measurement which is the subject of this thesis. The diagnosis of work measurement pathology, as contained in Chapter Four, builds directly from this section, as augmented by the works of Goldratt discussed in the previous section.

Basic Concepts and Definitions. Stafford Beer defines cybernetics as "the science of effective organization" (6:13, 7:ix); "management is . . . the profession of regulation and therefore of effective organization, of which cybernetics is the science" (7:x). The idea of systemic self-determination, or implicit (or intrinsic) control, which is the touchstone of cybernetics, has been recognized in Eastern philosophy for over 5000 years (5:299). In fact, Beer refers to ancient Hindu scripture, circa 3000 B.C., which embody cybernetic theory:

In reality, action is entirely the outcome of all the modes of nature's attributes; moreover only he whose intellect is deluded by egotism is so ignorant that he presumes 'I am doing this'.
(5:299)

What cybernetics has discovered is that all complex, probabilistic systems share the same fundamental principles of control which govern invariances among the adaptive connectivity of their parts to ensure viability (7). These invariances are the focus of cybernetics which then essentially becomes the study of methods for achieving and maintaining viability -- the charter of management. Further, the component parts of the system are treated as "black boxes," whose inner workings need not be understood; the focus of cybernetics is then solely on the interaction, or adaptive connectivity, among systemic components. Beer's two Regulatory Aphorisms, underscore the power of cybernetics in this regard:

The First Regulatory Aphorism - It is not necessary to enter the black box to understand the nature of the function it performs.

The Second Regulatory Aphorism - It is not necessary to enter the black box to calculate the variety that it potentially may generate. (8:40, 47)

One of Beer's major criticisms of our organizations, and the orthodox management theory used in controlling them, is the propensity to try to enter the black boxes of the operations in the belief that such is necessary for control. Hence the explosive proliferation of ever-larger computerized information systems, for detailed data gathering on

operations, which amount to nothing more than electronic archives of the corporation. Falsely believing that operational data, electronically manipulated many times over can convey information useful in controlling future operations, management is today suffering from a glut of computer output and computer generated reports masquerading as information. On the contrary, Beer believes that not only is it impossible for management to cope with the complexity within the black boxes comprising the producing operations, it is also impossible to formulate any sound management control apparatus which adequately interrelates and governs the myriad of complex activities within operations so as to ensure organizational viability. The utility of cybernetics for managers of modern organizations lies again in the focus on connectivity and invariance among systemic components, freeing the manager to concentrate on essential information for controlling operations and ensuring viability.

A discussion of several basic concepts, necessary in the development and understanding of the VSM, follow. These concepts include: systems and systemic viability, variety and its implications for management style, and coenetic variables and homeostatic loops.

Systems and Systemic Viability. Stafford Beer, as Eliyahu M. Goldratt, believes that nothing definitive about a system may be discussed unless the purpose of the system is

first recognized. Further, Beer attributes systemic purpose to one of two things: purpose is either that which the observer declares or the actual output of the system which implicitly defines systemic purpose. Of course, the declaration (of the observer) and the response, or output, of the system may be different in which case either the declaration must be altered or the system must be altered to achieve the desired response. Declaration and response, as the basis of cybernetic measurement and control, will be addressed below.

According to Beer, ". . . the System . . . is what we declare it to be . . . moreover, there are a great many things that can be scientifically said about systems that will avail us nothing in managing systems whose nature and purpose are not already agreed in advance" (8:11). Recognition of systemic purpose discloses the location of systemic boundaries. Without recognition of purpose therefore, systemic boundaries cannot be established; without recognition of systemic boundaries, there can be no clear identification of the entity we choose to call the system. "What [this] means is that we have to agree on the convention about the nature, the boundaries, and the purposes of any System before we can agree on what is to count as fact" (8:10).

Also, like Goldratt, Beer believes that the orthodox ideas about systems, or organizations, prevent management from achieving and maintaining viability. According to Beer,

The conventions [of today's managerial language] do not fully account for the systemic realities. The attempt to question the fit is impossible within the conventions; and if the conventions are breached, then the suggestions cannot be heard. This kind of deafness on the part of established managements is a major factor in the lethal resistance to industrial change that is eroding the viability of our society. (8:13-14)

Further, Beer recognizes the inherent problems in the orthodox practices which focus on suboptimization: "We could have set priorities between the subsystems, considering each on its own merit, and in so doing we could have failed to understand the first thing about the nature of the system as a whole" (8:20). In summary, lack of a clearly defined purpose, the constraint of orthodox management conventions, and suboptimization all work against managers who are responsible for the viability of the organization; any one or a combination of these three will prevent the establishment and/or maintenance of a viable system.

Beer defines viability as the capability of the organization to maintain a separate existence within a specified, external environment known as the metasystem (7:1, 8:113). This definition runs counterintuitive to orthodoxy which usually connotes financial soundness or profitability - in short, economic viability -- with the term viability because Beer views such economic considerations as

constraints under which the organization must operate rather than the goals of the enterprise (7:x-xi, 8:113). Systems achieve and maintain viability provided they possess an inherent capability to adapt to their dynamic environment in such a way as to maintain stability within and among the systemic components. Such an inherent capability is possible only in the capacity of the system to generate variety; in effect, to manage the complexity thrown at the system by the environment. The design of such a system, and the design of the regulatory interaction among the systemic components and between the system and its environment, is the aspiration of Stafford Beer's Viable System Model (VSM), discussed below.

Variety and its Implications for Management Style.

Waelchli defines a system as "a bounded collection of three types of entities: elements, attributes of elements, and relationships among elements and attributes. Both attributes and relationships are characterized by functions called variables" (14:53). The state of a system at a point in time is therefore defined by the values of its variables. At a point in time, the modes of nature's attributes define a particular state of nature as referenced in the above quote from Hindu scripture. The number of possible values that the system's variables may attain indicates the complexity of the system. Systems that may exhibit numerous possible variable values, and therein assume numerous different states, are more complex than those systems which are limited to a lesser

number of possible states. The measure of complexity, or the number of possible states that a system might assume, is known as variety (6:13, 7:21).

Ashby's Law of Requisite Variety, fundamental to cybernetic theory, states that only variety can destroy, or absorb variety (3:207). This implies that the only way to control a complex system is for the controlling mechanism or system to generate at least as much variety as the system being controlled. Again, according to Waelchli:

The concept of systemic control operates at two levels. First is physiological control, required to allow a system to continue in existence; the values of all of the essential variables are held within physiologically set tolerances. If physiological control fails, the system dies.

The second level is operational control, or the control of one system by another. This also requires physiological control, but in addition requires the maintenance of the values of a set of variables (essential or otherwise), chosen by the controlling system, according to its purpose for existence, within tolerances set by the controlling system. If operational control fails, the system can still live, but (by definition) it fails to accomplish its purpose. Ashby's Law governs both types of control. (14:54)

There are three methods that the controlling mechanism or organization may employ to generate the surplus variety it requires to control another system. The controlling system may: 1) amplify its own variety in excess of the system to be controlled; 2) achieve a parity, or requisite variety with the system to be controlled; 3) attenuate the variety of the

system to be controlled to a lesser amount than that of the controlling system (14:55). The practice of management, in the name of organizational control, therefore becomes an exercise in continuous design of effective variety amplification and attenuation mechanisms which will be discussed below; in Beer's terms, the manager needs to be a "variety engineer." In addition, as mentioned in Chapter One, the measurements which management employs to indicate the state of systemic control must themselves have sufficient variety to absorb the variety of states of the system to be controlled.

Management's choice of variety generation necessary for control of the organization dictates what is typically referred to as management style or technique. Waelchli categorizes such management variety control techniques, or management style, as either algorithmic or heuristic in nature (14:56). The algorithmic technique(s) are rule-based management methods, best suited for relatively simple problems, which seek to reduce situational variety for management decision-making. Conversely, heuristic techniques begin with expansion of situational variety which in turn requires expansion of the variety of the controller to arrive at a decision after "enlightened search" (14:56).

Management control of systems or organizations is accomplished through the simultaneous attenuation of situational variety and the amplification of managerial

variety. "From a historical perspective, methods of situational variety reduction [,or algorithmic models,] seem to have entered conscious management theory and practice first" (14:58). This appears only logical since management itself was devised to cope with the increasing complexity of larger work groups, industrialization and the world in general through the industrial revolution. Chief among the architects of management theory aimed at situational variety reduction were Frederick W. Taylor and Henri Fayol, both of whom worked within what is now recognized as the closed system model of the organization wherein the organization is considered independent of its environment (14:60,62).

As discussed previously, Frederick Taylor's belief was that there were "certain universal and systematic ways of approaching every type of human labor that led to the most efficient accomplishment of work [and that] management should precisely define the job and even the exact methodology of the work" (14:60-61). In this algorithmic approach, management unilaterally determines what to produce and the organization then sets about to produce the good or service according to the optimal procedure, or algorithm. The worker's role is then simply to execute the algorithm. "The worker's inherent variety is here considered entropic; what management wants is a precise, obedient and tireless low-variety machine" (14:69). Waelchli concludes,

Where does the Taylor approach succeed? It succeeds where correct execution of a protocol or adherence to an algorithmic method produces the desired product or correct outcome; where the correct means guarantee the desired end. It succeeds where work can be simplified to rote; where work is best performed by machines, and where economic motivation dominates. It succeeds where man works alone, or does repetitive tasks with simple machinery. It succeeds, in short, in non-complex systems where man does work of low variety. The essence of scientific management is the design of low-variety jobs that any man can do. Taylor's method does not appear to succeed as well where the work requires heuristic rather than algorithmic behavior. (14:62)

The heuristic model, recognizing the inherent dependency of the organization on the environment and therein the far greater complexity that must be managed, "takes on a suprasystemic, close-to-the-customer form, of the Drucker, Ouchi, Peters, Waterman . . . genere (14:69)." Here, the final product (good or service) is determined jointly among the worker, management and the customer through continual interaction and refinement of objectives and goals. The worker then partly assumes a managerial role, participating in the unfolding of the organization in the marketplace and, indeed to some degree in the management of the market itself. Now management, rather than suppressing the variety of the worker as done in the algorithmic model, seeks to focus on and use the enormous variety generated by the workforce; the worker is now part of the variety amplification channel of management rather than a source of added organizational variety which management must seek to attenuate. Here, Waelchli concludes,

The worker, with a shared corporate value system and corporate goals embedded in his soul, and with freedom, even a charge, to act intelligently on those values, has become, in a sense, an extension of management. He fulfills Drucker's test of a manager, one who accepts responsibility for contributing to the results of the enterprise. He is working, directly or indirectly, on the problems and complexity of the markets, adding his considerable variety on the side of management, and thus helping to institute organizational control in those markets. The worker has become an engine of managerial control variety amplification. In formal cybernetic terms, he applies his great variety to the task of controlling the complexity of the organization's environment and markets by acting to bring the variables targeted by management into the value ranges specified by management and maintaining them in those ranges. Ashby's second method of variety management now also appears in the manager's toolkit. (14:70-71)

Coenetic Variables and Homeostatic Loops. The previous section discussed variety as a measure of complexity wherein the degree of complexity reflected the possible number of distinguishable systemic states. According to Beer, ". . . in social systems . . . complexity tends to overwhelm those managers whose activities are not seriously directed towards viability but to short-term goals such as profit" (14:16). At first glance, the number of possible systemic states might seem limitless for highly complex, social systems such as a manufacturing organization. What cybernetics has discovered, however, is that not all distinguishable systemic states are equally likely to manifest themselves. In short, systems, both biological and social, are probabilistic, not because merely, as is often

supposed, legislation or regulation effectively restrains variety proliferation but because of the operation of a coenetic variable which simultaneously delimits the variety of both environmental circumstances and systemic regulatory responses (14:16).

The coenetic variable, as essentially described by Beer, Sommerhoff and Ashby (although under different notation in each case), operates to cause the system to converge on to a subsequent occurrence; "in the very process of disturbing environmental circumstances, the coenetic variable evokes a response that converges on an adaptive outcome" (14:16).

This concept was evolved by Beer into what he labels "intrinsic control" through a self-vetoing homeostat (5:291-293). Beer defines a homeostat, originally articulated by Ross Ashby, as a "mechanism for achieving stability -- the constancy of some critical variable (its output)" (5:290). A later definition by Beer spoke to a control device which recognizes and corrects threats to the system not considered by the designer (9:108). This last qualification, "not considered by the designer," is the key to what Beer calls "ultrastability" and characterizes the self-vetoing homeostatic loop. Figure 4 depicts a basic homeostatic control loop.

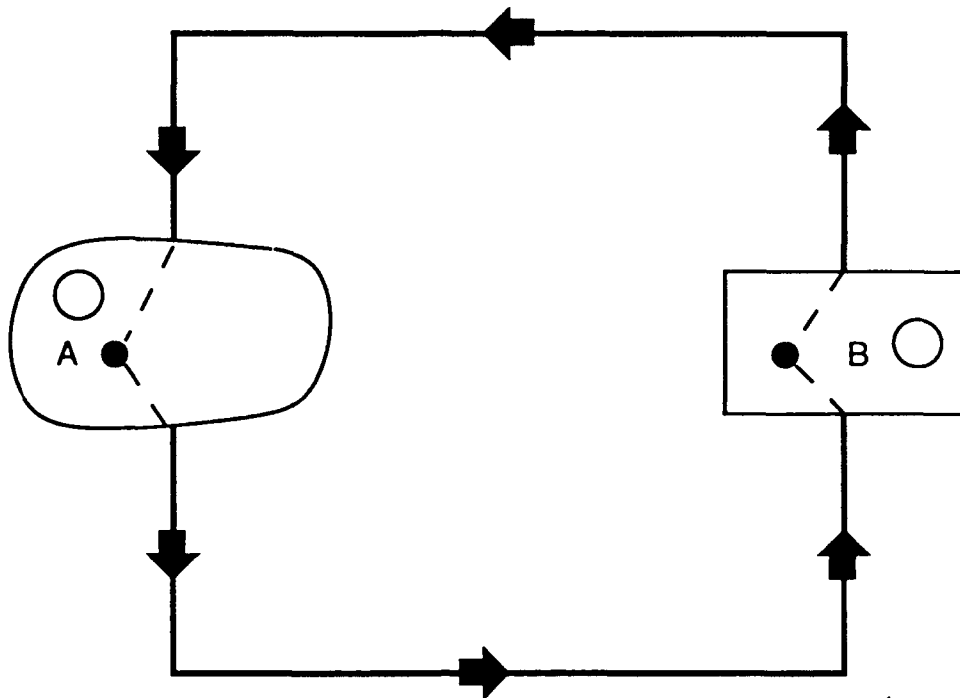


Figure 4. Basic Homeostatic Control Loop (5:291)

Management desires some state, indicative of stability, as defined when A and B are contained within the smaller circles inside the situation (on the left) and the control (the box on the right). The method of achieving stability is then described by Beer:

Control wishes to define a trajectory that will guide point B into the sub-set of acceptable states. Its decision about this is transmitted as an input to the situation, and is indeed an instruction intended to modify the state of affairs, without driving point A into the region of unacceptable states [outside the small, inner circle]. If the analytical way of looking at things proves successful when this happens, all will be well. Point A will be changed, but will remain in the region of desirable states; the new information about the situation transmitted to control will enable point B to follow the planned trajectory into its own region of desirable states. (5:292).

The self-vetoing homeostat activity entails continuous interrogation of A and B (control and situation) by the other and subsequent adjustment. Control continues to veto every B that is unacceptable and force A to change its state until an acceptable B is achieved. So long as the time required to achieve equilibrium within the loop is less than the time between systemic disturbances, stability is achievable; if not, the system will oscillate continuously and fail to remain viable. But probabilistic systems, by their nature, delimit alternatives and, although not predictable in exact content, they are largely predictable in form. As Beer concludes in Decision and Control,

A coenetic variable diminishes proliferating variety by preempting certain sets of the possible range of states. Secondly, variety is diminished by feedback of an annihilating kind [error-correcting negative feedback] Third, variety is cut by a learning mechanism which biases the alleged randomness of mutations -- thereby creating an epigenetic landscape. (5:369)

This quality of probabilistic systems (predictable form and unpredictable content) has significant implications where organizational modelling and cybernetic measurement schema are concerned as will be discussed below.

Stafford Beer's Viable System Model (VSM). Figure 5 describes a viable system, showing the relative positions of the environment, the viable system and management, as a realistic representation of the manner in which these three entities operate and interface on a daily basis; management

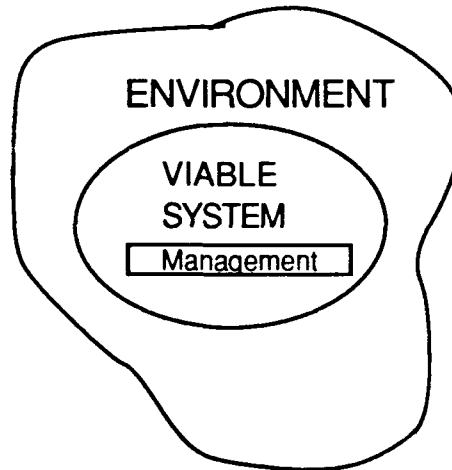


Figure 5. The Basic Viable System (14:79)

contained within the viable system which is contained within the environment. Note that although management does interface with the environment, or metasystem, it can only do so in the context of the viable system. Note also that the relative size of the enclosure, formed by the boundaries of each of these three entities, depicts the relative amount of variety each may generate; the variety of management is less than that of the operations which, in turn, is less than that of the environment.

In Figure 6, the three entities of the viable system have been separated to illustrate the variety attenuation and amplification loops that must exist between management and operations and between operations and the environment. These amplification-attenuation loops are homeostatic. Indeed, according to Beer, "The model of any viable system, VSM, was

devised from the beginning (the early 'fifties) in terms of sets of interlocking Ashbean homeostats" (14:17).

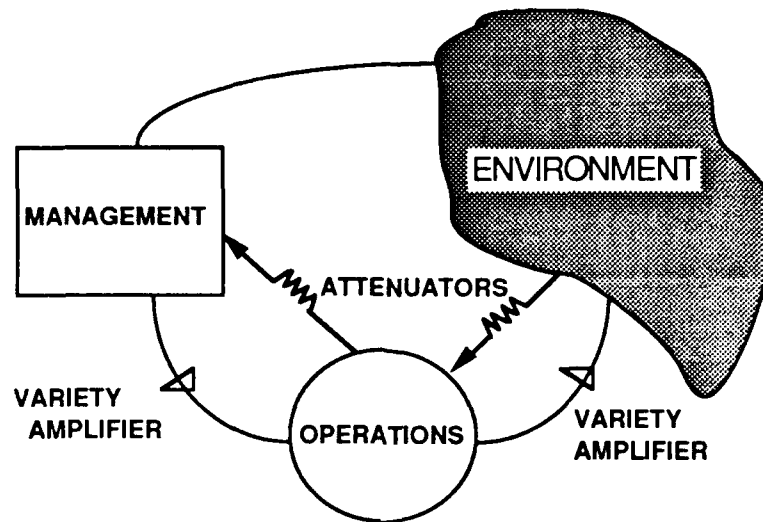


Figure 6. Entities of the Viable System (14:57)

A complete, two-dimensional representation of the VSM is shown in Figure 7, adapted from Espejo and Harnden's book, The Viable System Model: Interpretations and Applications of Stafford Beer's VSM. The VSM identifies five subsystems and their homeostatic interactions necessary and sufficient to maintain the viability of the system at any level of recursion. This concept of recursion, which Beer likens to chinese boxes, each containing and contained in another, is fundamental to the cybernetic property of invariance of the adaptive connectivity among components both at the subsystem and systemic levels. Every level of recursion precisely

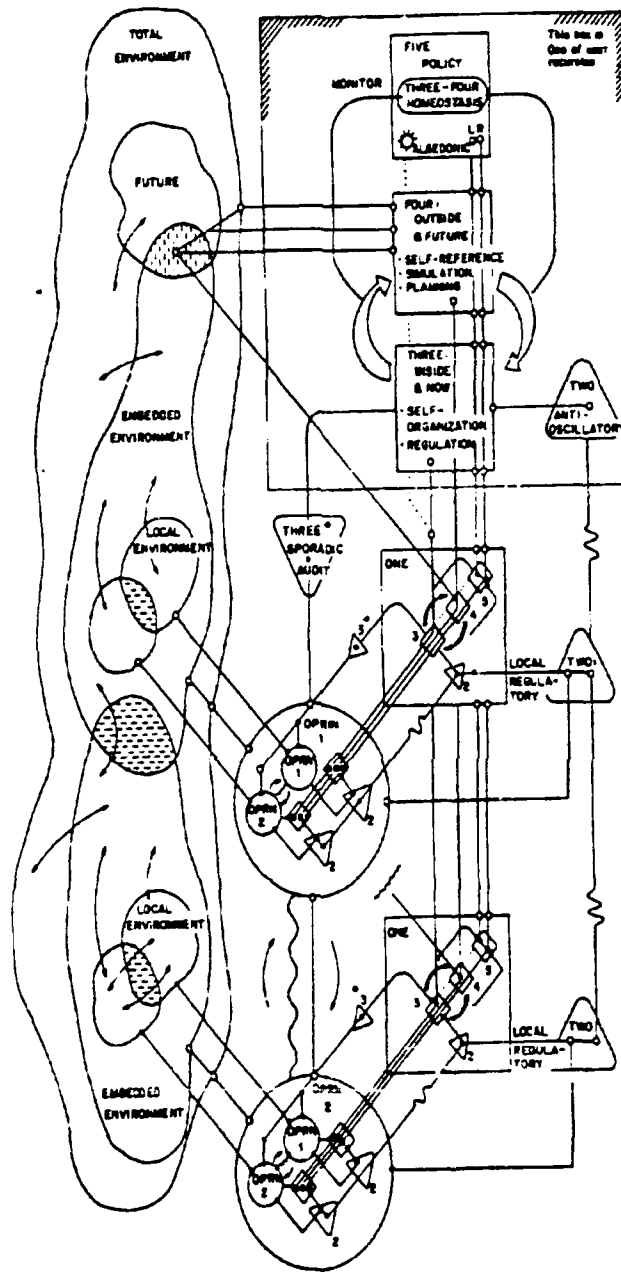


Figure 7. The Viable System Model (14:23)

duplicates the other in terms of the number and types of subsystems and connectivity. Each system may be contained in a number of recursive dimensions, which Beer conceptualizes as the spokes of a wheel (7:6). In his book, Diagnosing the System for Organizations, Beer gives an example of recursive dimensions using an individual person as the system in focus; this person may be part of one recursive dimension or chain which extends upward through church, community, state and nation and part of a different recursive chain which runs upward through job, work group, department, division, company and so on (7:6). For diagnosis and analysis, the system in focus is chosen and the next higher and lower level of recursion within the particular dimension identified (diagnosis is discussed below).

System ONE. The first of the five subsystems of the VSM is System ONE whose activities are solely those which produce the organization according to the declared systemic purpose. All other activities within the viable system, outside of System ONE, are support activities that are part of management and characterized by Beer as part of System ONE's metasytem. Systems TWO through FIVE are therefore metasytemic to System ONE for any given level of recursion and dedicated to stabilizing the internal and external environment of the viable system; the biological name for this stability is homeostasis (7:9). A given viable system usually has more than a single subsidiary viable

system embedment (operation) within System ONE, which among them produce the organization, but seldom has more than seven or eight subsidiaries or else a level of recursion may have been omitted in the analysis (7:19). Identification of System ONE operations and the metasytem again are dependent upon the declared purpose of the organization and therefore vary from firm to firm; what is a System ONE in one company may well be metasytemic in another company. For example, data processing may be System ONE in a firm which sells data processing services to other companies and will otherwise be considered metasytemic in a manufacturing firm which produces say pharmaceutical products.

System ONE is represented in Figure 7, at the recursive level of the system in focus, as a circle (the operations) connected to a square (the management box for System ONE) via homeostatic loops formed by System THREE Audit, System TWO and the command channel (all to be discussed below). Note that each System ONE contains a complete viable system (Systems ONE through FIVE) at the next lower level of recursion and that the System ONE management box, which contain Systems THREE through FIVE (to be discussed below) facilitate the internal organizational link between the various levels of recursion; this is the manifestation of the invariance property discussed earlier. Note also that the System ONE operations have a direct link to their local environment(s), which overlap with one another, and a direct

link with each other, all such links being homeostatic in nature.

System TWO. The second of the five subsystems comprising the VSM is System TWO, the regulatory center for the system in focus, indicated as a triangle in Figure 7. System TWO functions in the vertical domain, outside of the command channel, to damp oscillations inherent in System ONE as the operations interact with one another, the environment, and/or management in their daily activities of producing the organization. Management must always strike a balance between the autonomy allowed System ONE and constraint of subsidiary viable systems, delimiting the proliferation of System ONE's variety, only to the extent necessary for organizational cohesion as dictated by the Law of Requisite Variety (discussed above). As Beer states, "Constraint within the institution that exceeds the minimal variety reduction that is needed to ensure the cohesion that betokens viability, is oppressive" (8:173).

Since the variety of the subsidiary viable systems, operating as System ONE for the system in focus, is large by nature, any system that is designed to absorb the variety of System ONE, and therein function as an antioscillatory, must itself possess high variety. However, as Beer states, "the vertical linkage in the managerial domain [i.e., the command channels], which runs to the metasystem, must operate with minimal variety in relation to corporate cohesion, if

autonomy is to be upheld" (8:176). Therefore, System TWO must operate as a high-variety apparatus outside of the command channel. As such, System TWO is a service to System ONE, engaged to delimit the variety of operational interactions only to the extent necessary to prevent oscillation; this requires that System ONE participate in the development of System TWO.

Beer's examples of Systems TWO include the production schedule, the school classroom reservation list and course timetable, an executive secretary -- in short, any person's action or any planning or scheduling activity or document which essentially coordinates and integrates the ongoing activities of the operations so as to assist their smooth functioning through the avoidance of conflicts over limited resources (8:177-181). The trouble with most firms, according to Beer, is that this necessary damping of oscillation devolves into the imposition of an overabundance of mandatory rules and regulations which destroys the existing variety of the operations and therein prevents the viability of the firm. In short, the command channel is viewed as the only means to guarantee cohesion by levying undue constraint on operations; System TWO is not recognized and therefore is severely atrophied in most companies. (8:180)

System THREE. System THREE, referred to by Beer as "the Inside and Now" (8:199), is concerned with the management of the day-to-day operations of the system in

focus. According to Beer, "System THREE is . . . typified by its metasystemic nature, and by the SYNOPTIC SYSTEMIC viewpoint from which it surveys the total activity of the operational elements of the enterprise" (8:202). In this capacity, System THREE fulfills the synergistic requirement between adaptability and stability in ensuring viability as described in Figure 1 (Chapter One). System THREE is also aware of the antioscillatory activity of System TWO, since System TWO is its own subsystem" (8:202), for which it is responsible (7:86). Beer suggests that the carrying out of System THREE synergistic policies is perhaps best undertaken through co-opting the heads of the managerial units in System ONE to ensure the minimal metasystemic intervention in the autonomy of the operations (8:207).

System THREE and the management of each subsidiary viable system therefore negotiate a "resource bargain" wherein System ONE carries out its assigned activities with the resources given to it by System THREE and, in turn, system ONE is accountable to System THREE for successful completion of assigned operational activities (7:38-40). Beer cites the Planning Programming and Budgeting system (PPBS) as a prime example of this resource bargain (7:88). In addition to the resource bargain and accountability, both a part of the command axis, System THREE must also impose some minimal variety constraints on System ONE via the command channel. Such constraints generally are referred to

as legal and/or corporate requirements and policies. Thus there exist two homeostatic loops on the command axis between System ONE and System THREE: the resource bargain and the legal/corporate requirements-accountability loop.

The remaining System THREE function entails sporadic Audit (shown as System THREE* in Figure 7). Inherent in any management scheme is filtration, intentional or otherwise. System THREE cannot possibly keep abreast of all operational activities within System ONE. The information management therefore receives on the status of ongoing projects is filtered and condensed in effort by System ONE to only report on the significant aspects of operations. Unfortunately, owing to the differing perspectives of management and operations, some information might be filtered out of the operational data which management most needs to know. Thus System THREE must, from time to time, supplement the variety available to it via the command axis and System TWO and inquire directly of operations concerning the status of System ONE activities. According to Beer, System THREE* practices are ". . . capable of generating enormous variety. Such mechanisms work sporadically and -- by agreement with System ONE management -- penetrate straight to the operations themselves" (7:82). In this manner, not only can discrepancies in operations or reporting be found and corrected, System ONE may be given clear, direct instructions for future reporting which allow more meaningful information

to be passed to system THREE. Such a perspective on the role of the audit function is, according to Beer, nonexistent in most firms:

Poor managements, having too little insight or training, or suffering from corporate paranoia that has them feeling constantly threatened, disregard the filters and try to restore Requisite Variety on the control axis. That is, they disregard the resource bargain (where in principle the homeostatic message upward needs to be only OK), and invigilate the horizontal activities [i.e., operations] with all the zeal of an Inquisition.
(7:82)

System FOUR. Beer labels System FOUR as the subsystem concerned with the "outside and then" of the viable organization (8:225), concerned with identifying avenues for adaptability. Having developed systems ONE, TWO and THREE as that part of the viable system dedicated to the task of internal stability, Beer posits a System FOUR which must look outward to the environment in which the firm is embedded to discern a path for progress and to undertake regulation in this regard. As such, the purview of system FOUR is that of the organization's problematic environment (8:227-228, 237-238) which System FOUR continually monitors with a filtration system, of its own manufacture, to "recognize pattern in the unknown (but developing, immanent) future" (7:124). Toward this end, System FOUR seeks to "expand variety by contemplating rather than creating alternatives" (7:230). It does this by developing and maintaining a model of the system in focus (its system) and, infusing information about the

problematic environment, using this model to simulate and evaluate alternative future courses of action which the firm might undertake. System FOUR is therefore seen to "[house] the viable system's whole apparatus for adaptation" (8:235).

System FIVE. System FIVE provides logical closure to the VSM at any given level of recursion through its regulation of the tradeoff of corporate investment between System THREE and FOUR activity. In so doing, System FIVE furnishes the vision required to ensure organizational viability. As Beer states,

"System THREE originates messages (which it seeks to amplify) to System FOUR, which will make clear the needs of the existing business, and in particular elucidate the difficulties with which that existing business will be faced in trying to assimilate new developments that do not conform to the known technology and the established culture inside it. For its part, System FOUR originates (and amplifies) messages to System THREE which will illuminate future prospects that it expects the enterprise to confront, and in particular it will elucidate the threats and opportunities which it considers that the existing business must face. (8:255)

These messages flowing between Systems THREE and FOUR are, by nature, high variety and as such must exist outside of the low- variety command channel. Figure 7 illustrates this high-variety homeostatic loop between Systems THREE and FOUR and depicts the System FIVE intercession for regulation of the THREE-FOUR homeostasis -- a high-variety problem for System FIVE.

To contend with its inherent high-variety requirements, Beer envisions System FIVE as a variety sponge, borne out of the organizational climate, or "ethos," created by the senior management, corporate board, etc. comprising System FIVE, which delimits variety simply out of everyone's knowledge of what is expected within the corporation (7:124-125). The "boss" resides within this variety sponge, providing the final determination on the division of corporate time, talent, care, attention and money (8:253-254) between the ongoing Systems THREE-TWO-ONE operations which produce the organization and the System FOUR activities necessary to allow the organization to remain viable in the face of a dynamic external environment. In this manner, System FIVE provides corporate identity and self-awareness.

Because of the increasing rate of change in the external environment which we today face, determining this identity and the appropriate division of corporate investment between operations and development has become exceedingly difficult if done at all. Indeed the major failing of today's corporations, according to Beer, is that Systems FOUR and FIVE activities have collapsed into System THREE -- meaning top management has devolved into the crisis-management role - leaving untouched the machinery for adaptation and therefore continued viability (8:265-266).

Methodology for Diagnosis and Other Comments

on the VSM. As discussed above, local optima for System ONE (to borrow from Goldratt's terminology) would entail complete autonomy. Indeed, the variety of System ONE is directly proportional to its degree of autonomy (7:102). Clearly, however, complete autonomy of System ONE would result in a non-viable organization and the balancing act played by management therefore is between autonomy and constraint where System ONE is concerned. Stafford Beer thus postulates three axioms of management which address this balance between autonomy and cohesion and speak to the variety of the system in focus where interactions occur on the horizontal plane of System ONE, juxtaposed with the vertical plane where interaction occurs among the various subsystems (ONE through FIVE). These axioms are as follows:

The First Axiom of Management - The sum of horizontal variety disposed by n operational elements equals the sum of the vertical variety disposed on the six vertical components of corporate cohesion.

The Second Axiom of Management - The variety disposed by system THREE resulting from the operation of the First Axiom equals the variety disposed by System FOUR.

The Third Axiom of Management - The variety disposed by System FIVE equals the residual variety generated by the operation of the Second Axiom.
(8:217,298)

Also, as discussed in the introductory portions of this section, the links among the various components of the VSM

and between levels of recursion are self-vetoing homeostatic loops which play a critical role in achieving and maintaining organizational viability. Beer has postulated four Principles of Organization to guide management in the design and use of these homeostatic loops which are the communication channels of the organization, each with a differing variety and capacity according to its function within the precepts of the VSM. These four Principles of Organization are as follows:

The First Principle of Organization - Managerial, operational and environmental varieties, diffusing through an institutional system, tend to equate; they should be designed to do so with minimum damage to people and to cost.

The Second Principle of Organization - The four directional channels carrying information between the management unit, the operation, and the environment must each have a higher capacity to transmit a given amount of information relevant to variety selection in a given time than the originating subsystem has to generate it in that time. [Otherwise, the channel will not be able to distinguish among all the possible states of the originating subsystem and could therefore fail to communicate critical information relative to a particular state. In essence, a channel of insufficient capacity could serve as an unintentional variety attenuator to the detriment of management.]

The Third Principle of Organization - Wherever the information carried on a channel capable of distinguishing a given variety crosses a boundary, it undergoes transduction [defined as either the translation of the signal into the language of the receiving subsystem or the encoding of the language of the sending subsystem into the signal]; the variety of the transducer must be at least equivalent to the variety of the channel.

The Fourth Principle of Organization - The operation of the first three principles must be cyclically maintained through time without hiatus or lags. (8:97,99,101,258)

Beer and others have widely applied the VSM to organizations, large and small, throughout the world; from the whole of Allende's Chilean government, economic, and social system to the Swedish paper and packaging company, ASSI, which employs approximately 8000 people (14). Applications of the VSM and theoretical study continue today. Chief among the universities involved in graduate and post-graduate studies of the VSM are the University of Aston (Birmingham, UK), Manchester University (UK), University of Pennsylvania (The Wharton School), George Washington University, the Universities of Maryland and Maine. In addition, several computer adaptations and software packages either have been, or are being, developed from the VSM; the principle software shell being Cybersyn, marketed by Syncho, Inc. (14:350-351) and the major software package, "[an expert system] dedicated to the mapping of actual organizations onto the VSM" called Viplan (14:342).

The methodology for actual mapping of an individual organization onto the VSM for purposes of diagnosis is addressed in Stafford Beer's book entitled, Diagnosing The System For Organizations (7). Basically, the methodology involves mapping all of the various existing elements (people, policies and functions) of the organization onto the the VSM to identify which elements fulfill which of the

purposes of the five subsystems discussed above. Care must be taken to ensure that the standard organizational chart is not used to accomplish this mapping. While the standard 'org chart' may enable management to lay blame when things go wrong, "classical organizational formulae, such as production, sales and finance, cannot be of much help in thinking through the structure of a viable system" (7:10). Further, as Beer notes, "most of the incorrect inferences (and therefore the inopportune diagnoses and recommendations) made in applying the VSM derive from nominating activities that are not in themselves viable systems as if they were" (7:8). Any aspect of the organization which, upon completion of mapping, does not adhere to the structure of the VSM, the Four Principles of Organization, or the Three Axioms of Management (all discussed above), is diagnosed as a pathology, indicative of eventual nonviability, which requires redesign.

Beer's methodology for diagnosis is summarized below (7):

1. Define the systemic purpose of the organization of interest and use this definition to identify System ONE of the system in focus together with its environment. Identification of System ONE will entail listing all of the subsidiary viable systems (one level of recursion down) which among them produce the company according to the defined systemic purpose. In addition, identify the operational

units of the next higher level of recursion (of which the system in focus is one). Care must be taken to ensure that only one recursive dimension is considered in the analysis.

2. After identifying System ONE, list all of the departments and/or supporting groups which are metasytemic to System ONE at the recursive level of the system in focus. These metasytemic entities will later be categorized as System TWO, THREE, FOUR or FIVE according to the function they perform.

3. For the system in focus, identify the variety amplifiers and attenuators which exist on the two horizontal homeostatic loops -- between System ONE and its management and between System ONE and its environment -- and evaluate each loop on the basis of the Four Principles of Organization discussed previously. Identify and evaluate the homeostatic loops between each operational unit in the same manner.

4. Identify the possible modes of oscillation among the subsidiary viable systems which comprise System ONE together with the organizational functions or activities which are responsible for damping these oscillations. Those functions or activities which serve to damp the oscillations within System ONE constitute System TWO and must be perceived by system ONE as a service, rather than a requirement. Candidate elements of System TWO which are perceived by System ONE as requirements likely reside on the

command axis and therein lack sufficient variety to damp oscillation.

5. Identify all of the elements which comprise System THREE and THREE*, including those elements which comprise the resource baragain, accountability, and legal and corporate requirements functions found on the homeostatic loops between System THREE and the management of System ONE. Assess the degree of autonomy allowed System ONE relative to the requirement for corporate cohesion. Has System THREE disposed requisite variety to System ONE?

6. Identify all activites within the organization which comprise System FOUR, concerned with ensuring the organization's adaptation to the future through the continual monitoring of the problematic environment. Group these activities into major areas of interest (in the military we might include the mission area panels, strategic planners, research and development organizations and laboratories, etc.). Next look for areas of intersection or overlap among these major areas; if little to none is found, or commitees take the place of genuine interaction among the areas, System FOUR lacks requisite variety to complete its assigned tasks. Finally, assess the THREE-FOUR homeostat to insure that it complies with the Four Principles of Organization.

7. Identify System FIVE within the organization and assess his/its ability to provide closure to the system in focus. Essentially the components of System FIVE will be

those elements within the organization which serve to regulate the division of corporate resources between current operations and investment in the development of future courses of action. As such, the FIVE- THREE/FOUR homeostat must also be assessed to insure compliance with the Four Principles of Organization.

Measurement and Filtration Systems for Controlling Operations. Classical control engineering seeks to devise control mechanisms which make a given situation or activity behave according to specified performance criteria (5:300). Orthodox procedures for controlling operations adhere to this classical perspective, failing to recognize the critical difference between what Beer calls "artificial" and "world" situations (5:300) and the implications of these differences for the design of effective managerial controls for the organization. Beer defines an artificial situation as one created by the engineer, as opposed to a world situation which ". . . is usually some thriving, complex, uncertain, interacting collection of men and machines, materials and money; one may stumble across it as a going concern" (5:300). In cybernetic terms, control mechanisms for world situations simply cannot be designed according to classical control theory because the variety of the operational units, the interaction of these units, and the interaction of operations with the environment necessary for adaptation far exceeds the

capacity for variety generation by the controller. In short, orthodox management procedures for controlling operations, based on the classical control engineering approach, do not entail requisite variety and cannot ensure the viability of the organization.

Orthodox management control techniques employ numerous methods -- material requirements planning (MRP), managerial accounting, sales forecasting, work measurement standards -- each with a somewhat different view of systemic purpose, each necessarily defining differing system boundaries for control, and each with differing criteria for evaluating performance. In short, each method or discipline has its unique definition of the common "system" it is seeking to evaluate and control. As stated in Chapter One, none of the orthodox techniques address global, or world-view, optima; each is, instead a suboptimization technique. Reconciliation of the varying reports and performance indicators generated by each method is required in attempt to construct a coherent picture of corporate status. Frequently, the objectives or standards set for control by each of these orthodox methods are also at cross purposes from the systemic viewpoint. In short, the manager is confronted with conflicting data; he doesn't know who to believe. As Beer states,

Just how many control systems does [the manager] want? How many different standards can [the manager] accommodate in evaluating expectations from how many different sources? These matters, it is submitted, are getting out of hand in modern

businesses. The control function becomes subdivided geographically, functionally and professionally; a selection of empires is sustained; the whole arrangement is both confusing and costly [Cybernetics] acknowledges the control function as an indivisible whole and seeks to devise arrangements for exercising it . . . but that fact will not be used to avoid the practical implications for any one specialized function.
(5:305)

Certainly control mechanisms for world situations can be designed. Cybernetics has shown, however, that such control mechanisms must operate on the entire structure as a self-vetoing homeostat. Such a meta-control mechanism is thereby capable of collectively amplifying organizational variety in response to disturbances in the environment. Contrary to the classical approach, "Arrangements are not made to record every possible state of the system and every best answer to every state. Arrangements are instead made to ensure that the system will be able to find, or to learn to find, the answers to problems it is set" (5:302). This section will summarize Beer's critique of orthodox management control techniques in light of his recommendations for the design of a cybernetic control mechanism for the viable system. Beer's proposed measurement and filtration schema, in support of cybernetic control mechanisms, will also be addressed. Schematic representations of both the orthodox and cybernetic control mechanisms, discussed below, are shown in Figures 8 and 9.

The Cybernetic Critique of Orthodox Control Systems. In his book Decision and Control, Stafford Beer

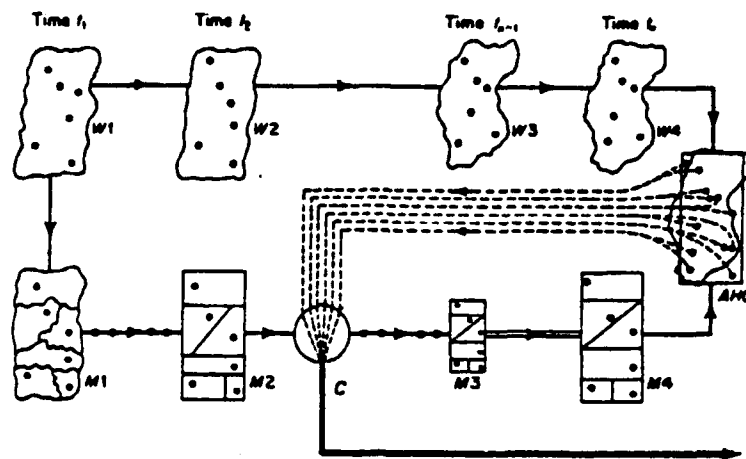


Figure 8. The Orthodox Control Mechanism (5:311)

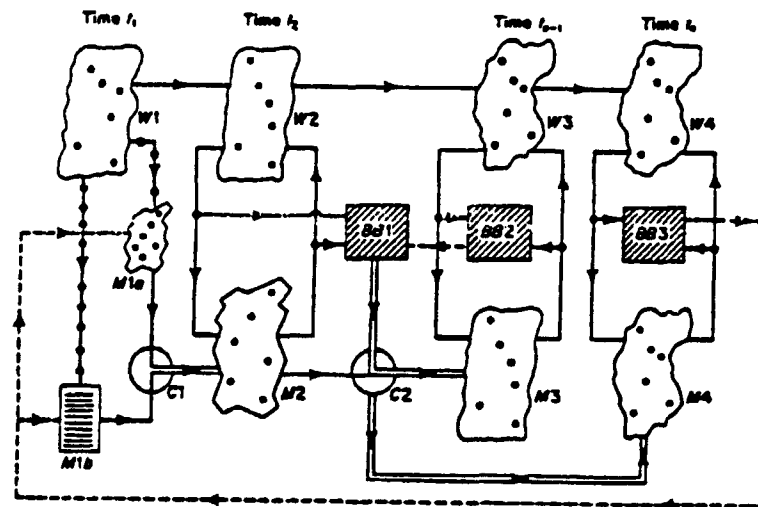


Figure 9. The Cybernetic Control Mechanism (3:328)

describes the shortcomings of orthodox control systems in cybernetic terms. This critique is summarized here. The first step in the orthodox approach to control, once the world situation of interest has been recognized, is to seek a way to reduce its variety to allow the modeler to formulate a conceptual model of the organization. Beer refers to this conceptual model as "M1" which corresponds to the world situation, "W1," at time t1 (5:305). Next, M1 is divided into convenient subfunctions or groups depending upon the intended use of the model for control; an example of such subgroupings are workstations on a production floor. Since M1 is a conceptual model of an actual complex process, the variety of M1 is further reduced through the act of describing or specifying this model in written form (or computer program). The resultant, low-variety model of W1 that is "committed to paper" is "M2" at time t2 (5:306). In summary, as Beer states, "[the people involved] were all trying to cope with complexity by exhausting the real-life proliferation of variety in the model M2" (5:307).

The model M2 has several failings which render it inadequate for control purposes. First and foremost, a low-variety model in the service of a controller necessarily delimits controller variety far below that required by Ashby's Law of Requisite Variety for design of an adequate control function; M2 clearly cannot include all of the exceptions, idiosyncracies, and interdependencies of the

system which will be manifested in actual operations. Secondly, because of the time required for gathering data from operations necessary to construct M2, the model is outdated the moment it is completed. Rather than M2 being an accurate model of the world situation W2 at time t2, as is the intent of the modeler, M2 is instead a model of W1 at time t1. Depending upon the amount of time lapse between t2 and t1, M2 may still come reasonably close to reflecting the actual system or it may not, but management cannot be confident in its ability to project M2 into the future with any predictive value at least until validation of the model, which requires yet more time -- perhaps as much as a year or two.

In using M2 for forecasting, management (the controller) must now begin to draw upon the historical data of the operations and use this data, in conjunction with M2, to predict some future set of events which are a subset of M2. Typically, the historical data required to augment M2 and allow the construction of a forecast are not complete. Nonetheless, the combination of data and M2 yield a predictive model, M3, which is of yet lower variety than M2. To arrive at a final prediction of the world situation, W4, the predictive model (M3) is then amplified to generate a model of the world situation, M4. What management is left with in the end, as a forecast of the world situation, is then M4 which has devolved through a series of variety

delimiting steps. Not only is M4 hopelessly outdated, having originated from M1 at time t1 and augmented by data from W2 at time t2, it also possesses at best a fraction of the variety of the world situation it purports to predict. World situations are dynamic; "people have slightly changed their responsibilities, the technical rules of the game have altered somewhat, the contracts with the customer are not quite the same as they were before, some people are working harder and others less hard than before" (5:309). As Beer summarizes, "To the objective cybernetician, then, the shop floor is a control system generating variety for the purpose of controlling the planning office, and not vice versa" (5:310).

To this point, orthodox management control techniques generally recognize the shortcomings of predictive models and therein attempt to add variety back into these models through the introduction of feedback mechanisms which compare each actual event in the world situation with its predictor(s) and report any differences back to the control office for future reference. In this manner, the control office can update M2 and more accurately predict future world situations; the proportion of completely new events is usually low enough so that the model, augmented by feedback, becomes fairly accurate at prediction. But what management has ended up with, despite the usual intention of keeping the model simple enough that it cannot go wrong, is an arrangement so simple

that it cannot go right (5:311) and an ever-expanding control office of monumental proportions. The requirement to continuously generate feedback necessary to maintain the predictive capability of the model, results in the control office attempting to "exhaustively enumerate the proliferating variety of the world situation" (5:312). Herein lies the genesis of the explosive proliferation of our modern massive data storage and retrieval systems which inundate the manager with output.

Development of a Cybernetic Control System. A cybernetic system for control of the organization involves a major paradigm shift from orthodoxy, providing management with a true management information system (MIS). Gone is the need for the huge data storage and retrieval systems. Gone too are the voluminous computer runs and outputs which overwhelm managers with more data than they can ever hope to assimilate and digest. In place of all this is a smaller, less expensive, and far more accurate system to assist in the management of the organization. The cybernetic-based MIS combines systemic process modelling with continuous, near-real-time (NRT) Levels of Achievement (known as actuality, capability, and potentiality) and statistical analysis via a black-box time-series comparator of predicted and actual events (also known as declaration and response) to focus management attention on problem areas and to furnish current, reliable predictors of future events. Further, as discussed

below, cybernetic systems for control do not employ error-correcting negative feedback as the orthodox systems do; data on every conceivable event within the world situation is therefore no longer required and lag times between the model and the world situation it is intended to predict are nearly zero. Instead, the cybernetic system, owing to the variety-generation capabilities both within the predictive model and the black box comparators feed information forward to automatically adjust predictions for future world situations based upon a model that requires alterations only if the logical or structural relationships of the organization are altered.

The cybernetic approach to control entails the development of a model of the world situation (W1) consisting of two distinct submodels: a structural model of W1 which Beer calls "M1a" (5:313), and a parametric model of W1 called "M1b" (5:316). Both M1a and M1b greatly reduce the variety of the world situation as M1 does in the orthodox approach. However, unlike the orthodox M1, these submodels possess a latent capacity for variety generation, and when recombined in accordance with forecast requirements, yield a model with requisite variety for any world situation. M1a is comprised of a combination of mathematical, statistical, or logical statements about the relationships of the world situation expressed as constraints on the system which constitute networks of conditional decision (5:315). Where necessary,

homomorphic transformations of these structural relationships may also be accomplished to further reduce the variety of the model while maintaining the capacity for variety re-generation. Thus M1a may be likened to the basic flow diagram or logic network one might find in a competent simulation package such as SLAM II (Simulation Language for Alternative Modelling). Following this analogy of the simulation package, M1b may then be likened to the actual numerical data input to the simulation which quantifies the structural relationships and describes the world situation of interest. However, rather than attempt to record all of the numerical data necessary to augment M1a and therein describe all possible world situations, Beer recommends that only performance optima be recorded in M1b to derive "a numerical model which properly reflects the fundamental quantitative relationships in which classes of events stand to each other" (5:317). This forms the basis for all subsequent predictive models derived from M1a and M1b. Since M1b contains only numerical optima, no ordinary fluctuations in operations efficiency affect the relationships between M1A and M1b; the model is therefore valid for all future predictions.

Once M1a and M1b are constructed, the control office can then combine them to formulate M2 for W2 at time t2. Together, W2 and M2, now with requisite variety, comprise a self-regulating homeostat. A black box (BB1) is inserted in this homeostatic loop to map W2 and M2 onto each other and

monitor the instantaneous interaction between the world situation and the model. BB1 operates by taking a statistically adequate sample of world-situation events as they occur and compares, in ratio form, the actual events with the predictions of the model. The ratios are collected as a time series and, through the use of discriminate analysis, separated into statistical populations indicative of the genere of processes at work in the world situation. A pattern develops in the ratios that allows management to distinguish among different classes of events in W2 based upon the common attributes of these events; something the orthodox analytical model cannot do. The output of BB1 can therefore be designed not as simply the ratio between W2 and M2 but as "a designation of membership of its appropriate statistical population" (5:326).

Now the control office, with the output of both the black box and M2, generates M3 for W3 one time epoch prior to the forecast of interest, again inserting a black box (BB2) in the homeostatic loop between the model and the world situation, and provides an information stream back to BB1 which statistically modifies the operation of BB1. In this fashion, the control system is provided the capability to learn and closure is obtained in the predictive function of the controller; this explains why the initial models M1a and M1b only need revision if the logic or structure of the organization changes.

The final step in the construction of the cybernetic control mechanism is the combination of outputs from BB1, BB2, and M3 into M4 for prediction of W4 at time now. A third black box, BB3, is inserted into the homeostatic loop between W4 and M4 with an information stream back to M1a and M1b, providing final closure to the controller for updating the structural and parametric models in the event of substantial changes in the flow of operations or work practices which change the parametrics. The system is self-correcting and provides predictions of world situations based upon models that are current as of the time of the actual events of interest.

Beer has advocated the use of Quantified Flow Charts (QFCs), which are "iconic representations of the wealth-producing, or result-generating, parts of each organization" (14:340), that highlight major flows and (like Goldratt) process bottlenecks. These QFCs visually represent M1a, isolate those processes requiring management attention, and indicate the requirements for location and design of monitors for the metasystem (management). Thus the QFCs (or M1a) provide the motivation for measurement of the three Levels of Achievement mentioned above. In the cybernetic analysis of Chapter Four, we shall nominate Goldratt's three measures -- Throughput, Inventory, and Operational Expense -- as the basis for measurement of Beer's three Levels of Achievement - actuality, capability and potentiality. We end up with a 3

x 3 matrix for expressing Goldratt's necessary and sufficient measures in terms of the global goal, recast in cybernetic terms for control. Beer's three Levels of Achievement are defined as follows.

Actuality - what "we" are managing to do now, with existing resources, under existing constraints;

Capability - what "we" could be doing (still right now) with existing resources, under existing constraints, if we really worked at it;

Potentiality - what "we" ought to be doing by developing our resources and removing constraints, although still operating within the bounds of what is already known to be feasible. (4:163)

Each Level of Achievement originates within its respective planning level in the organization. Beer identifies three such planning levels: Tactical, Strategic, and Normative (4:167- 180). According to Beer, "Strategic Planning in System THREE (with its tactical planning offshoot in System TWO) has to do with actuality [the measure of which is obtained from System ONE]" (8:361). Normative Planning resides within System FOUR/FIVE metasytem for identification of potential futures. As such, both capability and potentiality measures are under the purview of Systems FOUR and FIVE.

Capability and potentiality are determined through the FOUR/FIVE homeostat, assisted by the systemic modelling and problematic environment monitoring activities of System FOUR. Once valid measures are obtained for actuality, through

the time series analysis of the black-box ratios discussed above, three Measures of Achievement are derived which serve as the metalanguage for higher levels of recursion. The Measures of Achievement are defined by Beer as follows:

Productivity - the ratio of actuality and capability

Latency - the ratio of capability and potentiality

Performance - expressed as either the ratio of actuality and potentiality or the product of latency and productivity (4:163)

As an example of the use of the Levels and Measures of Achievement, consider a subsidiary firm whose System FOUR has discerned a market potential for 500 units of product. This same firm is capable of producing 400 units, known through the measure of capability, and the validated actual measure of throughput is 300 units. Cast in the metalanguage of the Measures of Achievement, Productivity is 0.75, Latency is 0.8, and Performance is 0.6. Immediately the higher level of recursion (presumably the corporate management) can see that there are improvements which can be made in Productivity to fully exploit Capability and increase throughput to 400 units, but not to the extent of fully meeting market demand. Management then has the basis for decision-making; it either must furnish more resources to the subsidiary or choose not to fill 100 units of market demand as indicated by the Latency ratio.

The VSM and Cybernetic Control Systems - Summary.

Stafford Beer's VSM provides management with a unifying, systemic paradigm to use either in the design of new organizations or in the diagnosis of pathologies in existing organizations for prescription of redesign. The goal of the cybernetic approach, as reflected in the structure of the VSM is to ensure the organization's long-term viability. Toward this end, cybernetics and the VSM form the basis for a unique MIS to control the operations of the organization by providing near-real-time information indicative of incipient instability. Combined with Goldratt's three necessary and sufficient measures of actuality for System ONE operations, the VSM MIS ensures that not only will all relevant information be provided to management in a timely manner but that only relevant information will be prepared.

III. Methodology

Stafford Beer's paradigm of the viable system in management cybernetics will guide the overall research into the management problem and hypotheses outlined in Chapter One. The research method will involve mapping of the general functions of the acquisition process onto Beer's VSM, a diagnosis of the current defense market and its implications for viability of the defense acquisition system, and a cybernetic diagnosis of the pathologies inherent in MIL-STD-1567 according to Beer's suggested method for diagnosis as described in Chapter Two. The analysis will proceed by declaring a systemic purpose for the defense acquisition system and then nominating two systems in focus, the SPO and the defense contractor, to allow the subsequent nomination of the role of Work Measurement within the VSM.

Since hypotheses one and two speak to the general condition of the non-viability of the defense market, they will be investigated and analyzed together in diagnosis of the current defense market. Also, since hypotheses three and four together encompass the systemic phenomena of variety, autonomy, constraint, and measurement, they will be investigated and analyzed together in diagnosis of the pathologies of Work Measurement specifically.

Beer's diagnosis and cybernetic theory employed in the analysis of Work Measurement will be augmented by Goldratt's

Theory of Constraints, also described in Chapter Two: Simulation, using Simulation Language for Alternative Modelling II (SLAMII) (24), will be used to illustrate the effects of dependent events and statistical fluctuations in manufacturing processes in support of Goldratt's work and pertinent to the pathology of suboptimization apparent in Work Measurement and as addressed in hypotheses three and four.

A complete description of Stafford Beer's model of the viable system is contained in his two works, The Heart of Enterprise and Brain of The Firm. Beer's companion volume, entitled Diagnosing the System for Organizations, provides instructions in the application of his paradigm to existing systems for cybernetic analysis. These techniques will be employed in this research for the analysis of MIL-STD-1567 in the management of weapons acquisition programs. Goldratt's Theory of Constraints, which will augment the VSM analysis, is contained in his two books, The Goal and The Theory of Constraints.

Since this research is theoretical in nature, the details of work measurement, managerial cybernetic theory, and the Theory of Constraints, as discussed in Chapter Two will provide the source of information upon which to base the cybernetic diagnosis of MIL-STD-1567. Because of time and resource constraints, audit of existing Work Measurement data bases and exiting acquisition programs in attempt to

accurately reconstruct the contractor and DOD Systems ONE through FIVE functions and also the respective problematic environments as a means of comparison of cybernetic control mechanisms and Work Measurement will not be attempted. Such an attempt at reconstruction of these world situations is of questionable value since the only means of establishing the effectiveness of a cybernetic system for control on defense acquisition programs is to conduct a pilot program for cybernetic control on an actual acquisition effort as a cooperative endeavor between the defense contractor and the SPO. Such a program has not yet been attempted or even considered.

IV. Diagnosis

A. Introduction

This chapter will present a cybernetic evaluation of MIL-STD-1567, Work Measurement, following Stafford Beer's VSM and suggested method for diagnosis and Eliyahu M. Goldratt's Theory of Constraints, both discussed in Chapter Two, with observations from the author's experience on the TR-1/U-2 aircraft production program. First, we will declare a systemic purpose for the acquisition system and then nominate the system in focus and the systemic role of Work Measurement in the viable system by mapping the general functions of the acquisition process onto the VSM. Next, the systemic role of Work Measurement in the viable system will be diagnosed for pathologies. In Chapter Five, a prescription for suggested systemic re-design will be offered based upon the pathologies noted in this chapter.

B. Systemic Purpose, Nomination of the System In Focus and the Role of Work Measurement

Goldratt has suggested that the global goal of any firm is to make money. Certainly, a reasonable declaration of the global goal of the defense acquisition process is to acquire weapon systems which fulfill the needs of the users. Stafford Beer's work argues that the global goal of any organization must be to ensure viability. We will adopt here

viability as the global goal and suggest that both the contractor's goal of making money (a necessary condition for viability) and the goal of the acquisition process to acquire useful weapon systems are both subsumed in ensuring the viability of these respective organizations in the recursive dimension of the acquisition process.

Figure 10 illustrates the recursive dimension nominated for the analysis of Work Measurement in accordance with Beer's notation; this dimension, in general, is the recursive dimension for the USAF weapons acquisition function. The diagnosis and discussion to follow will consider two systems in focus. First, we will nominate the System Program Office (SPO) as the system in focus, with the defense contractor(s) serving as System ONE and the Program Executive Officer (PEO) as the metasytem of the SPO at the next higher level of recursion. Moving down one level of recursion, we will next nominate the defense contractor as the system in focus, with the contractor's producing subsidiaries serving as System ONE and the SPO as the metasytem at the next higher level of recursion. This will allow full discussion of the utility of Work Measurement within the recursive levels it logically must serve: the contractor and the SPO. Figures 11 and 12 illustrate these two systems in focus, respectively.

As shown in Figure 11, with the SPO as the system in focus and the contractor(s) serving as System ONE, System THREE activities are carried out primarily by the acquisition

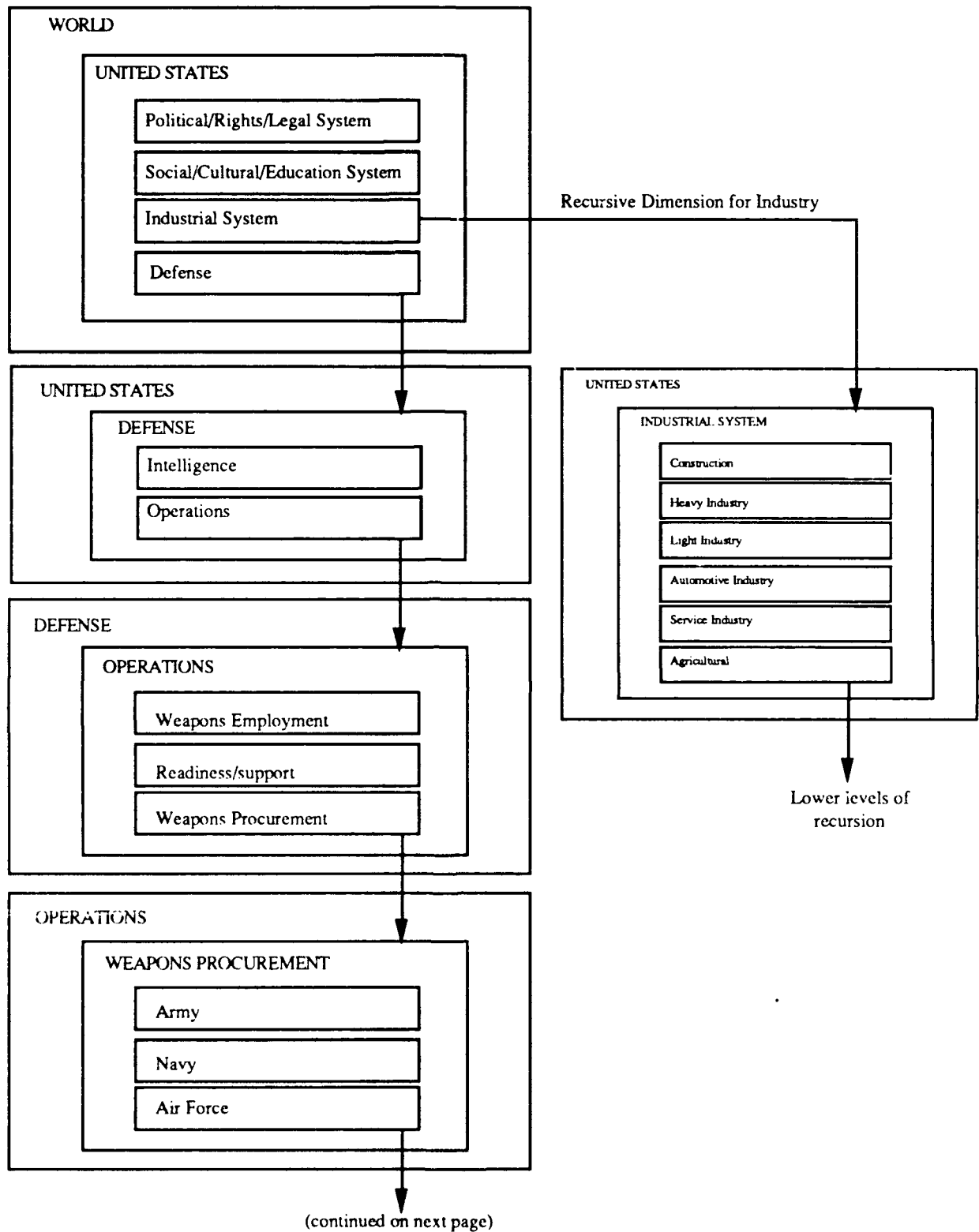


Figure 10. Recursive Dimension for Weapons Procurement

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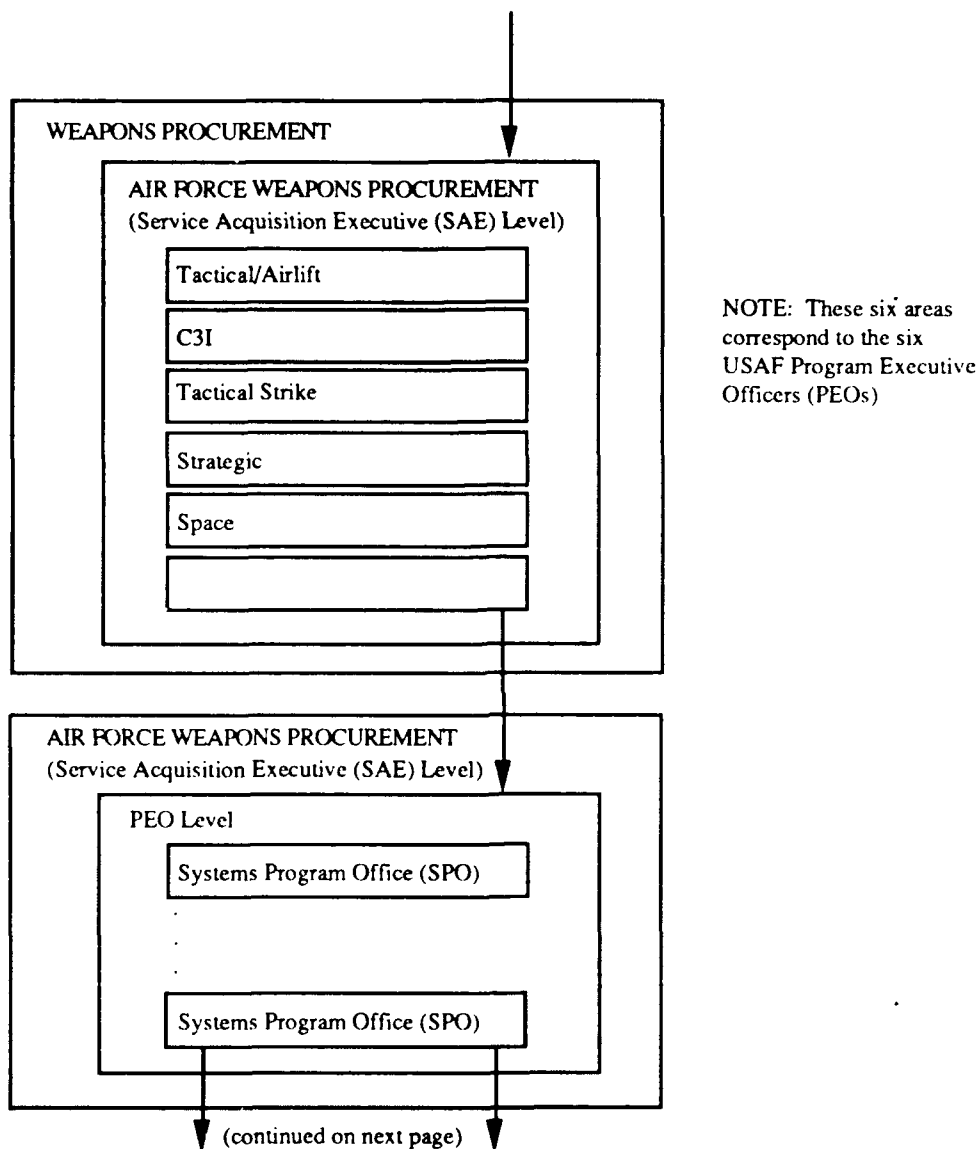


Figure 10. Recursive Dimension for Weapons Procurement (continued)

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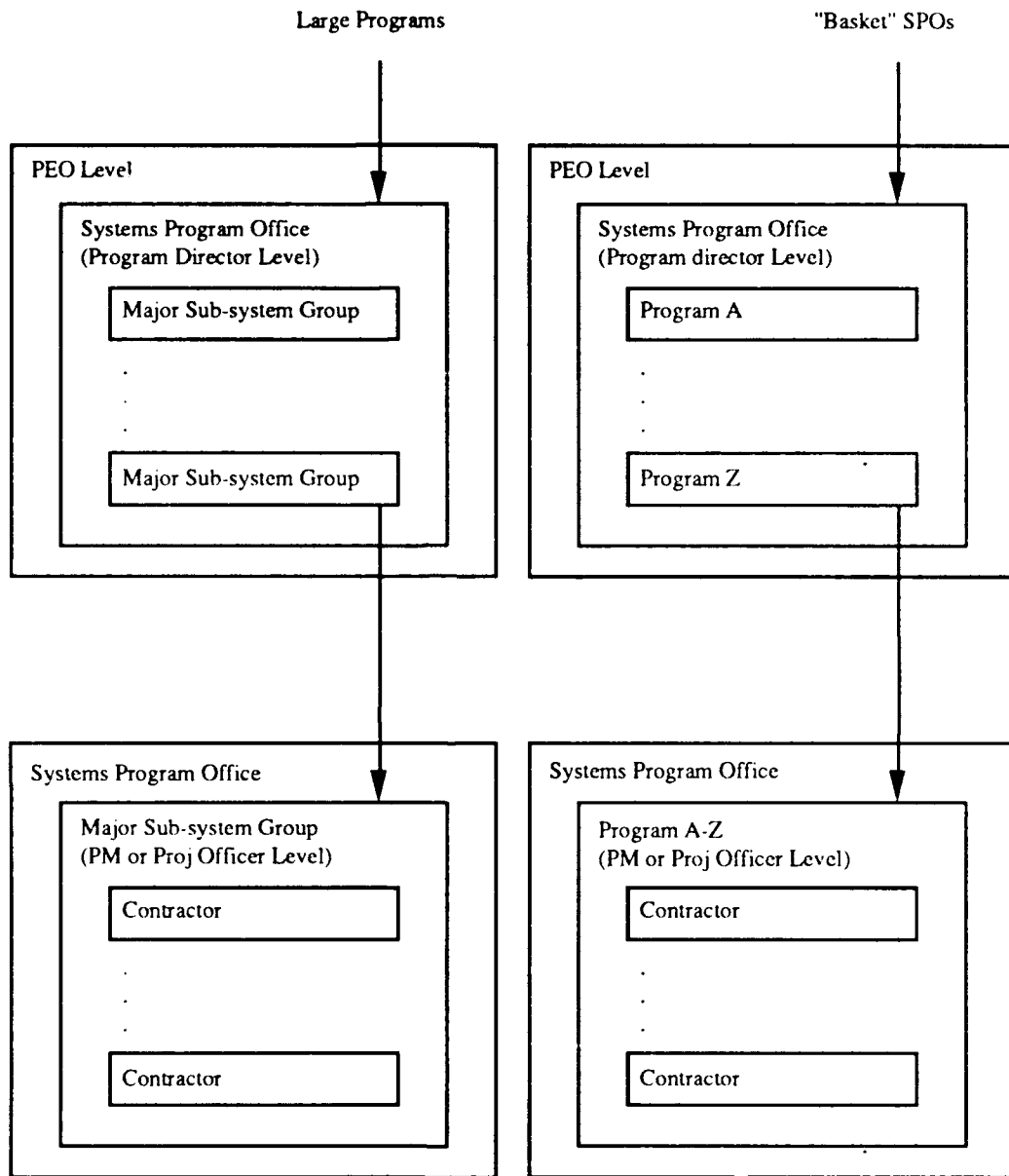


Figure 10. Recursive Dimension for Weapons Procurement (concluded)

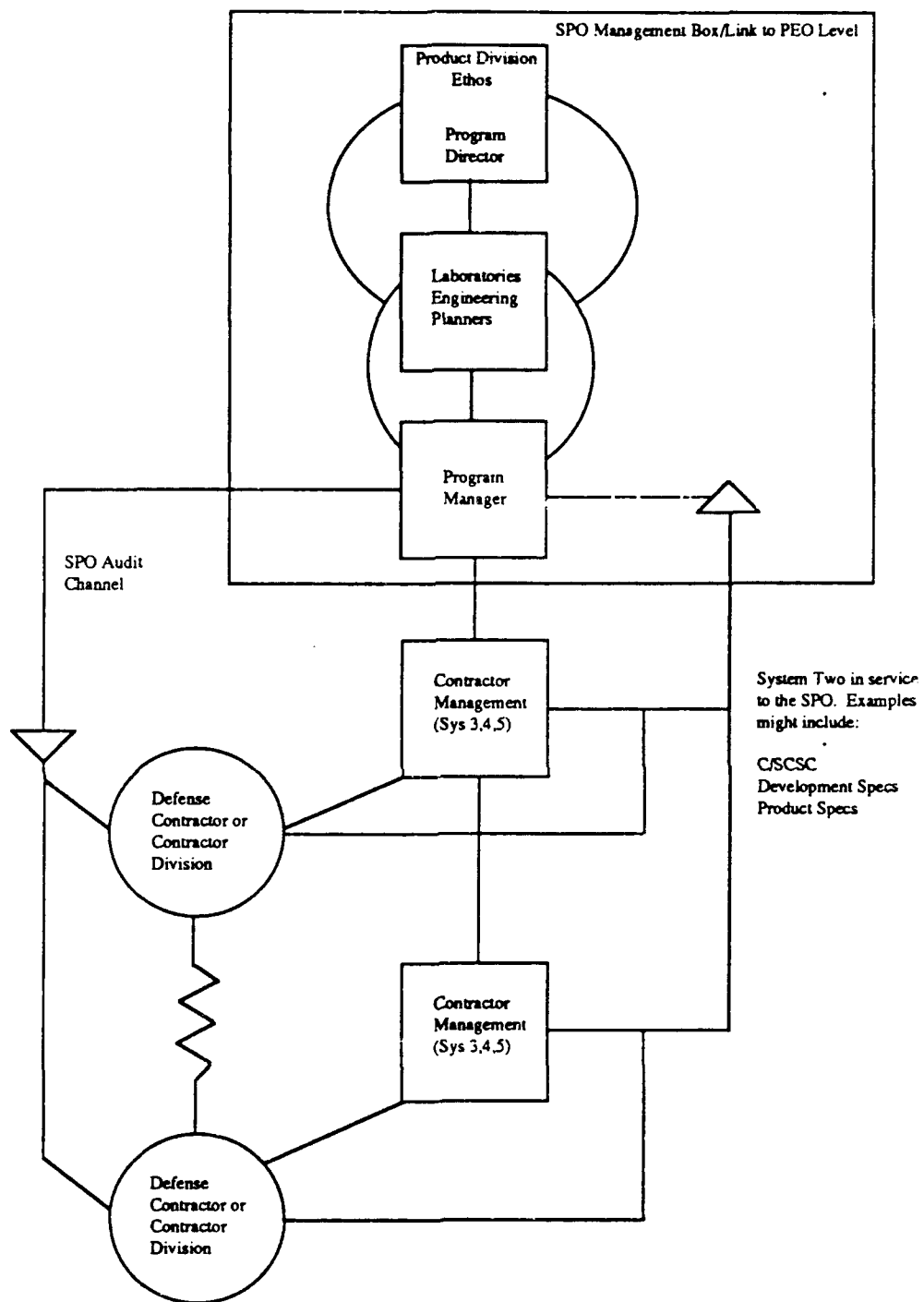


Figure 11. SPO as System in Focus

Program Manager (PM), with the assistance of the functional organizations or representatives (e.g., program control, contracting, etc.) within the SPO. We would expect to find System FIVE activities carried out by the Program, or SPO, Director (SPD) within the ethos of the Product Division. System FOUR activities may involve both the PM and the SPD, as well as other development-oriented activities within the Product Division whose output might affect a particular acquisition program directly or tangentially (e.g., a research laboratory). Command-channel activities, sporadic audit, and System FIVE monitoring of the THREE-FOUR homeostat are all extremely complex, intermeshed, activities, often difficult to disentangle and identify directly; many candidate activities for these functions may be nominated at all levels within the Product Division and individual SPOs but are beyond the scope of this diagnosis.

As shown in Figure 12, where the individual contractor is the system in focus and his subsidiary producing units (e.g., divisions within the corporation or product groups within a corporate division) serve as System ONE, System THREE activities are typically carried out by the PM equivalent within the contractor organization. Since defense contractors are typically matrixed organizations, as are DOD SPOs, System THREE of the contractor is generally augmented by functional groups or representatives. Within the System FIVE function, we would expect to find a General Manager, who

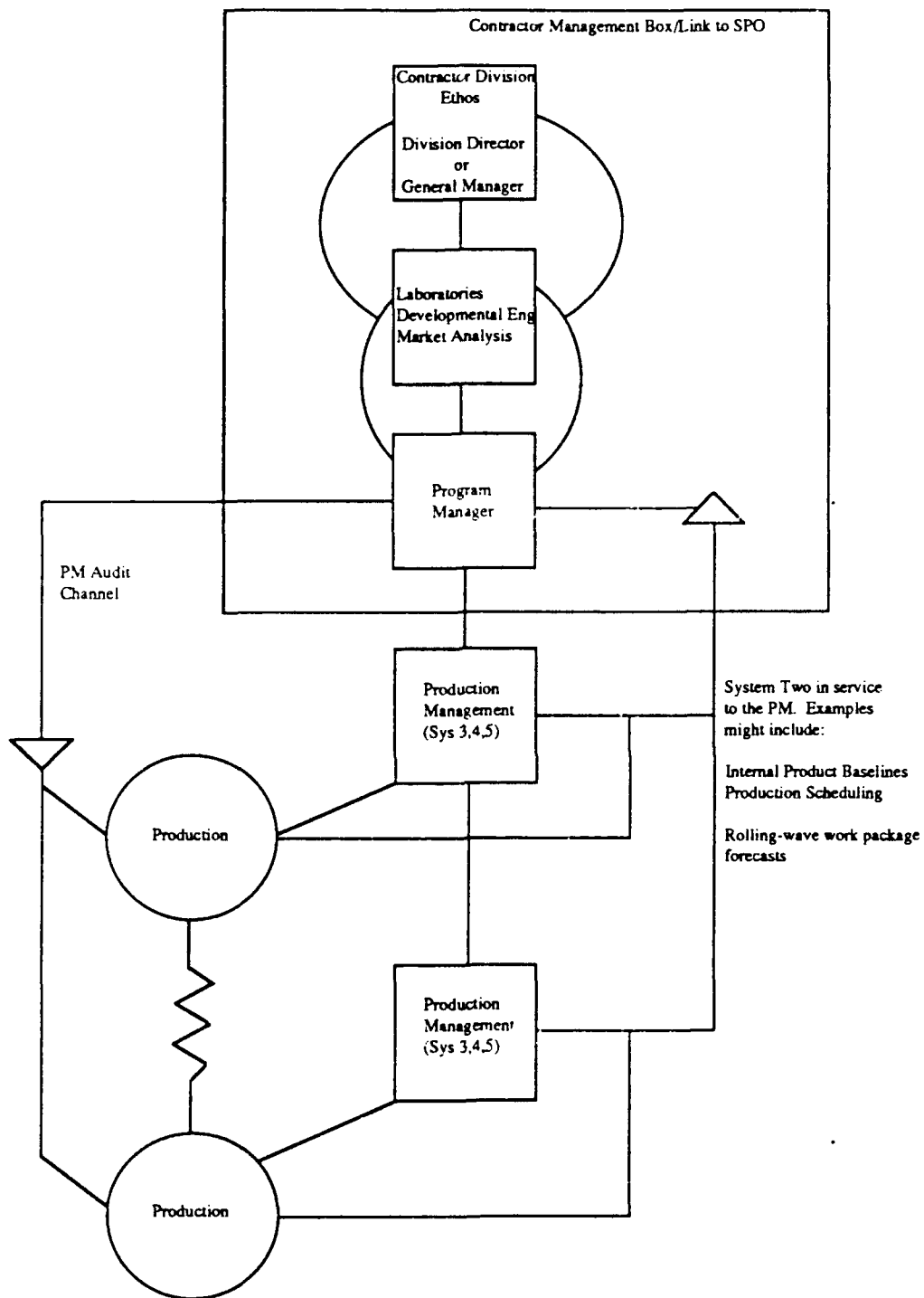


Figure 12. Contractor as System in Focus

is typically a corporate Vice President, within the ethos of the corporate culture, policy, and/or image -- typically aligned with the types of defense products produced and sensitivity of the programs the contractor handles. System FOUR of the contractor will generally involve development activities but with emphasis on what amounts to a specialized market research function to monitor the politico-defense environment which entails the users, Congress, the Pentagon, the System Command(s), the Product Divisions of the buying organization and, in some cases, representatives of foreign governments for foreign military sales. Contractor representatives are found at each of these levels, gathering data on the actions, beliefs, and requirements of all government officials involved in what collectively forms the contractor's problematic environment or product market which may be characterized as an oligopsony (a few producing firms with only a few customers).

System TWO activities at both the contractor and SPO levels of recursion typically involve some type of cost reporting, development and monitoring of product baselines or specifications, development and monitoring of program schedules (e.g., development, test, manufacturing, delivery), and numerous other related coordinating documents and activities. All of these vehicles are intended to provide management with a means of coordinating resources to fulfill program requirements, usually by establishing some form of

standard or measurable milestone to which actual performance is compared. If actuals differ from the standard(s) or milestone(s) by some predetermined margin, management is alerted to potential problems; investigation into the cause(s) is undertaken to formulate some type of corrective action, or "get-well," plan usually complete with its own milestones by which to assess the status and effectiveness of the corrective action(s). It is for these two levels of recursion, but especially where the contractor is the system in focus, that Goldratt's three measures of actuality should be applied: Throughput, Inventory, and Operational Expense.

Since Work Measurement intends to formulate standards by which to evaluate labor performance, determine the labor portion of program cost, and establish labor process time requirements as an input to production scheduling, we will nominate MIL-STD-1567 as an element of System TWO. The cybernetic analysis of the application of Work Measurement to weapon systems acquisition management will then follow the diagnosis of Work Measurement as a System TWO function within the VSM.

C. The Defense Market

Figure 10, as discussed previously, shows the recursive dimension under study for the diagnosis of Work Measurement as a System TWO function. Note that Figure 10 shows defense

and industry as subsidiary viable systems which help to produce that system which we call the United States. An alternative model might be constructed to show defense subsumed by the industrial system as one of its subsidiaries; the dependence of industry, the industrial base, and the economy in general (as produced by the industrial system) upon defense might suggest this alternative. Yet another alternative would be to include defense as one of the subsidiary viable systems of the United States and place the industrial system within the list of subsidiaries which produce defense; defense planners might logically argue for this arrangement, saying that our defense needs should determine, at least in part, what type of industrial system we ought to evolve and maintain. The arrangement chosen, and depicted in Figure 10, however, allows interaction between industry and defense along the homeostatic loop between System ONE subsidiaries (Figure 7) as well as recognizing those portions of the respective industry and defense environments which are separate and those portions which overlap and interact according to the VSM (Figure 7):

Today, the distinction between industry and defense, and the proper role of the two functions, is frequently unclear. Worse, the oversight and micromanagement actions of Congress seem to mandate that both industry and defense are subsumed within the political/rights/legal subsidiary of the U.S.; witness the passage of defense authorization language which

mandates the reporting of labor standards in defense. procurement as discussed in Chapter Two. The basic question often arises, "Who's the customer?" Correspondingly, one might logically ask, "Who formulates the market?" Does the defense establishment provide a market, i.e., an opportunity for someone to sell a product to the government at a competitive price to fulfill a valid defense need, for the defense industry? Or do a few large defense contractors instead provide a line of goods which the government might buy from them at some "competitive" price -- where "competitive" is an adjective meaning the highest-possible? And finally, what forces are strongest in formulating the defense market: national security objectives or political pursuits? These are the first indications of the pathology within the defense market, with the result that there is no viable defense market by which the defense industry may establish criteria for stability.

Witness in the last several months what has happened in the Fiscal 91 defense appropriation process: the number of B-2 bombers "required" to fulfill U.S. defense needs has dropped from 132 to 75 to zero; the C-17 cargo/airlift aircraft program has been effectively canceled; the Air Force Advanced Tactical Fighter (ATF) program has been under sufficient political fire as to cast serious doubt on whether any such aircraft will ever be produced. And this list speaks to only some of the major programs within the Air

Force -- countless other, nonmajor programs within the USAF and other programs, large and small, within the other services oscillate in a similar fashion which proves devastating to the viability of the defense industry. Production of the Navy's F-14 fighter aircraft, which the DOD requested be terminated, was re-instated by Congress, based solely on political considerations and not on defense needs. Finally, it's no secret, indeed it has become the standing joke, that the best way for a defense contractor to keep his program alive in the Congress is to spread the work around to subcontractors in as many Congressional districts as possible. Fox recounts that Rockwell International Corporation, in the manufacture of the B-1B bomber, "spread the work among 5,200 subcontractors in 48 states and 400 congressional districts" (15:92). What has happened is that the political, industrial, and defense functions have all become intertwined, each trying to control the other to its advantage; there is no global goal for defense and there is, therefore, no viable defense market. Without a global goal, there can be no global optimization since measures of productivity, as described by Goldratt, cannot be defined.

D. Effects of a Non-viable Defense Market

System FOUR exists within the viable system to monitor the firm's problematic environment -- essentially the market,

both current and prospective futures. Quite simply, without a viable market, no valid indications of either capability or potentiality may be developed since, as noted above, without a global goal, there can be no criteria for systemic measurement. Hence, no criteria for viability may be established. The defense market, for the reasons discussed above, is of such high variety, owing to the synergy of the variety generators within Congress, the DOD, and the problematic environment of the U.S. as a whole (e.g., the world military, political, and economic situation), that neither the defense contractor nor the DOD can achieve requisite variety within their respective systems. Further, the rate of systemic disturbance perpetrated on the defense industry is greater than the reaction or adaptation time within the defense industry. In the absence of a global goal, or systemic perspective, and in traditional fashion of delimiting inbound variety, both Congress and the DOD have chosen to proliferate hundreds of statutes, regulations, standards, and policies rather than deploy variety to the subsidiaries. It is precisely this proliferation of organizationally constraining regulation that destroys defense industry adaptivity. Fox describes the abundance of regulation affecting weapons procurement, saying that in 1947, the Armed Services Procurement Regulation (ASPR) numbered approximately 125 pages versus the over 1200 pages of Defense Acquisition Regulation (DAR) and Federal

Acquisition Regulation (FAR) in 1987 (15:17). Each of these regulations deal with a particular aspect of weapons acquisition; they are suboptimization routines, many anchored in cost accounting theory, proliferated along the central command axis and within the resource bargain in attempt to legislate stability.

According to Mr. Bob Fox, President of the Avraham Y. Goldratt Institute, in an address to the Air Force Institute of Technology (AFIT) on 3 Aug 90, we are in an era of a second industrial revolution which is worldwide. This revolution is the transition from the cost world, where numerous cost-accounting practices govern decision-making, to the throughput world, where decisions are based upon global optima using the three necessary and sufficient measures for management discussed in Chapter Two (throughput, inventory, and operational expense). One of the tenets of the Theory of Constraints, which embodies the throughput mentality, is that the organization's throughput must be balanced with, or set slightly below, market demand. Clearly, without a basis for determining market demand with any reliability, throughput cannot be set. In the end, without a viable market, the defense contractor is left to guesswork and open to continual systemic disturbances from his problematic environment while cost-accounting suboptimization procedures are mandated via the resource bargain between the government and contractor, forcing the contractor's attention on operating expense as

the only management indicator. Hypotheses one and two are confirmed. It seems ironic in today's era of Total Quality Management (TQM), that we should be perpetuating a system where contractor throughput cannot be set and procurement regulations require the contractor to concentrate on reducing operational expense when TQM, Just-In-Time (JIT), and TOC all place throughput first and operational expense last on the list of importance in controlling manufacturing operations.

E. Pathology Specific to Work Measurement

Three major areas of pathology are found to exist within the Work Measurement approach. First, from the TOC perspective, work measurement concentrates on individual processes as independent events within a production operation and implicitly ignores the global perspective subject to systemic constraints. Second, from the perspective of the VSM, work measurement, deployed by System THREE through the resource bargain as a "top-down" requirement, fails to afford the contractor requisite variety to manage his operation in pursuit of viability. Rather than enlisting the contractor to amplify the government's own variety in acquiring weapon systems, the government instead constrains the contractor's variety and incurs the added burden of controlling the contractor in the process; adding to the variety faced by the government management. Third, work measurement does not

facilitate the establishment of a cybernetic system for controlling operations as discussed in Chapter Two. We will now address each of these pathologies in turn.

Pathology: The Theory of Constraints Perspective. Mr. Bob Fox, in his address to AFIT on 3 Aug 90, best summed up the arguments against Work Measurement from the Theory of Constraints perspective when he stated, "Where dependent resources [or events] and statistical fluctuation exist, and they do in any plant, it makes no sense to concentrate on maximizing efficiency." Contrary to Kyser and Meade's assertion that productivity will increase if management sets a standard and so informs the employees (20:31), application of the Theory of Constraints proves conclusively that productivity is dependent upon systemic constraints, or bottlenecks, and has nothing to do with efficiencies of the individual processes considered in isolation. The premise of Work Measurement, as described by Keyser and Meade and discussed in Chapter Two is therefore false; productivity will not increase simply by setting a standard and letting people know what the standard is.

The whole of Work Measurement depends upon the analysis of individual activities or actions comprising a given task and a summation of the expected time for each to arrive at some standard time for the task. As discussed in detail in Chapter Two, various methods for determining the expected time of an activity have been recognized and constitute the

basis for classifying the type of time standard so derived. In determining standard times therefore, Work Measurement implicitly assumes that each individual activity or task is an independent event; consequently no recognition of dependent events, statistical fluctuation, and their effects on the overall system is made. The result is that the output of Work Measurement -- a time standard for a particular labor-intensive task or operation within the manufacturing process -- harbors intrinsic variances owing solely to the operation of dependent events coupled with statistical fluctuation. Each such time standard, itself a local optima, is then linked with all the other such standards for the whole of the process, again without regard for the dependency of operations or statistical fluctuation. The end result is a group of standards that possess an unknown magnitude of built-in variance and therein yield little to no actual predictive capability where labor requirements for the entire operation are concerned. If one is to further consider the effects of a plus-or-minus five percent error in pace rating, anywhere from a plus-or-minus ten to twenty percent deviation in PR&D allowance, and the tendency of companies to sample statistically-insignificant numbers of cycles for long operations, the problem of unknown, intrinsic variance in the time standard is further compounded. In the parlance of the cost analyst, the resulting labor estimates will likely be precisely wrong rather than approximately right. It is

little wonder then that considerable time is required to develop and implement a work measurement system. Often, the contractor will propose a two-to-three year timespan before predictive capability can be established; this tracks closely with Beer's analysis of orthodox control discussed in Chapter Two. Realization Factors, Labor Efficiencies, and Time Standards are all in a state of continuous fluctuation and revision.

Type I Standards, as described in Chapter Two, are required to reflect an accuracy of $\pm 10\%$ with a 90% confidence at the operation level. As Goldratt describes, where activities or operations are linearly dependent, statistical fluctuations are additive. To illustrate the effects of dependent processes coupled with statistical fluctuations, a simple example was constructed wherein five linear, dependent processes were simulated, each process having a Type I Standard Time of completion described by a normal random variable drawn from a common population. The mean time for completion of each of the five processes was chosen to be five time units (or minutes) so that the average time for completion of the entire process (i.e., one unit of raw material enters process one, is processed through all processes, and departs process five) should be 25 minutes (or time units). The simulation was run, using the Simulation Language for Alternative Modeling (SLAM II) package (24), for 300 time units (minutes) to correspond to roughly one day of

work. The schematic of the simulation model is shown in Figure 13. Figure 14 shows the simulation output which clearly indicates the accumulation of statistical fluctuations as the time through the five processes exceeds 36 time units at the end of the first simulated day (Appendix B contains the SLAM code, program formulation, and complete SLAM output).

The above example is an extremely simple one and represents what is, in effect, manufacturing Utopia. Certainly no manufacturing operation contains processes with expected times of completion which all originate from the same statistical population. Also, all systems have at least one bottleneck which was not considered in the above simulation either. Given the orthodox approach to costing and measurement of process efficiencies, the relationships among the processes and multiple dependencies are probably not well understood; the bottlenecks have not been identified. Goldratt's thesis is confirmed even in this simple illustration. Time standards for individual operations, no matter how accurate, tell management nothing about the capabilities, or the stability, and therefore the viability, of the system or process as a whole. Worse, the "efficiency" rating of any one individual might depend upon one or several previous operations in the process, causing erroneous performance ratings. As Deming tells us,

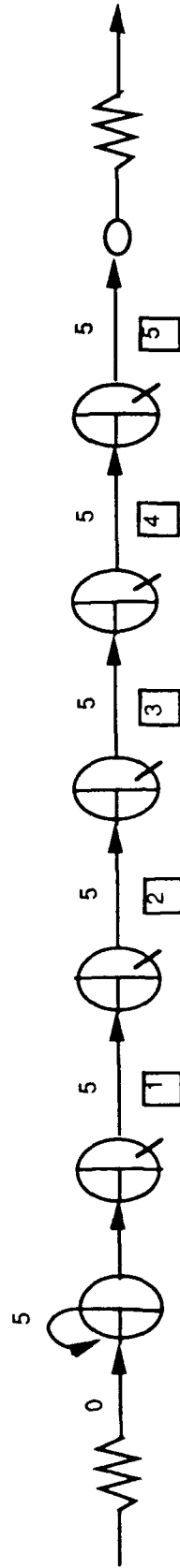


Figure 13. Schematic Diagram of Simulation Model

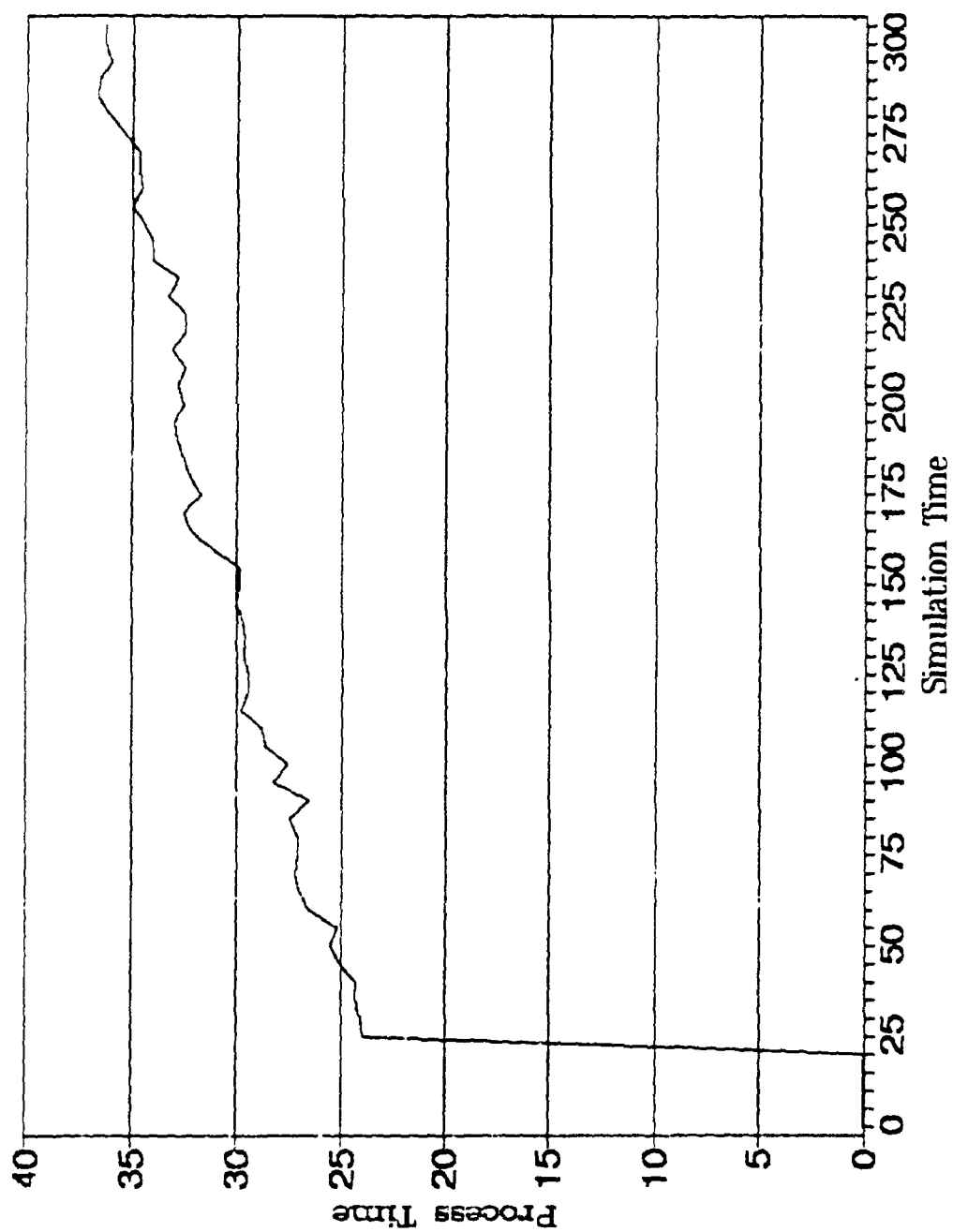


Figure 14. Process Time as a Function of Simulation Time

Everyone doing his best is not the answer. Everyone is doing his best. Recognition of the distinction between a stable system and an unstable one is vital for management. The responsibility for improvement of a stable system rests totally on the management. Understanding of a stable system discloses devastation of people wrought by the annual appraisal of performance A numerical goal that lies beyond the bounds of capability of a system will not be reached except at the expense of some other activity in the company, thus, in the end, raising total cost to the defeat of the company. (29:xi-xii)

Pathology: The Cybernetics Perspective. Work

Measurement, or any suboptimization routine which, by design, seeks to enter the black box of operations (as discussed in Chapter Two), lacks the variety to cope with the complexity once inside the black box. The sheer amount of historical and control-loop data required to sustain a Work Measurement system (e.g., the MTM system described in Chapter Two) stands in testament to its inherent lack of variety. Inasmuch as Work Measurement seeks, for purposes of managerial control, some optimum state for the individual processes which interact within the system, and does not seek instead a global optimum, the control function based on Work Measurement must constrain both the variety of the individual processes and the interactions among them to achieve requisite variety; this is in accordance both with Beer's First Axiom of Management and First Principle of Organization.

As described in Chapter Two, a managerial variety control technique which seeks to reduce situational variety

for managerial decision-making is algorithmic; Work Measurement falls into this category. Since Waeichli identified Frederick Taylor as a principal architect of algorithmic techniques and Work Measurement also originated with Taylor, it is not surprising that Work Measurement should be found to be an algorithmic approach. What is surprising is to find that such an approach is still considered as a means of control today given what we now know about Constraint Theory, Cybernetics, Self-managing Work Teams and the necessity of worker involvement in job design, and the reality of open systems within the environment of the marketplace.

Certainly in today's defense market, the product is determined jointly among the worker, the management and the customer. Also, where manual labor is involved in the manufacture of today's highly-sophisticated modern weapon systems, and where evolving technical requirements can cause frequent product design and production baseline changes, the work is usually of high, rather than low, variety. In addition, production runs are often low-volume; manual tasks rarely, if ever, become rote. If some tasks are rote, they should be automated. But the cost analyst might argue that the low-volume production lot doesn't justify the cost of automation. Then why does the same lot justify the cost of developing a standard which will never likely evolve to Type I in the time that production is actually taking place, much

less a suboptimum standard with inherent variance that tells management nothing about the viability of the overall process?

Cybernetics makes it clear that suboptimum, algorithmic control techniques only aggravate the problems of systemic control for management by making the worker an additional source of variety which must be controlled rather than a potential for management variety amplification, which the heuristic approach would favor, in the face of environmental complexity. As stated in the foreword, this author's experience rests primarily with the manufacture of the TR-1/U-2 aircraft -- the most highly labor-intensive aircraft produced for the USAF inventory today and an aircraft built under a heuristic, rather than an algorithmic, management approach.

Because of its extremely thin skin, the TR-1/U-2 aircraft was assembled almost entirely by hand. When manufacturing, quality, or performance anomalies surfaced, the workers teamed with the engineers and management to design the solution. The workers were continually designing ways to improve the process in recognition of the high variety of their tasks. In one instance when the USAF required a design change in the aircraft equipment pods, requesting that the contractor build a pod configuration which had never been built in house and had been done only as a retrofit by a mission equipment subcontractor up to that

point, the workers were asked to design the job; they completed the manufacture of the new pod configuration ahead of schedule and under cost without manufacturing quality problems or defects. All in all, the history of the TR-1/U-2 production program spoke for itself: all aircraft were completed on time or ahead of schedule and each production lot was under target cost. No Work Measurement techniques were employed. Instead, the worker was part of management's variety amplification process. Cost was not the primary measure of performance; process improvement and stability was the primary performance indicator and low cost emerged as a by-product of improvement.

Within the worker's involvement in the design of the work itself to amplify managerial variety, rests the genesis for the design of the antioscillatory mechanisms for System ONE operations which comprise System TWO. The Review of the Literature discussed Beer's mandate that System TWO, as a service to System ONE and operating outside the low-variety command axis, be designed, at least in part, by System ONE. Clearly, no one knows better where the process may be improved or the indications that something has gone awry in operations than the workers; candidate indicators and measures for progress and problems should originate with those in operations. Rather than allowing System ONE input into the design of System TWO, MIL-STD-1567A, although fulfilling a System TWO function, originates at the

metasystemic levels and becomes part of the resource bargain both between the SPO and PEO levels and between the SPO and contractor levels. As such, Work Measurement resides on the low-variety command axis and, as discussed above, cannot possibly possess requisite variety to adequately measure stability at the systemic level. As the Review of the Literature indicated, certainly System ONE, at both the contractor and SPO levels of recursion, perceives Work Measurement as a requirement and not a service as the controversy over Work Measurement continues. The model of the manufacturing organization, which Work Measurement implicitly develops and employs for measurement and control is simply inadequate for analysis and reporting of manufacturing process stability.

Orthodox and Cybernetic models and measurement and filtration systems for controlling operations were discussed in Chapter Two. Work Measurement certainly falls within the orthodox category as a control mechanism aimed at making a given labor-intensive manufacturing process behave according to some specified performance criteria, namely the Time Standard. In fact, it's the worker himself who is made to behave according to the Time Standard as part of the particular process. Implicit in this orthodox approach is the belief that the manufacturing process of interest is an artificial situation, one created by the industrial engineer or work analyst by virtue of the design of the process

according to standard data and known conditions. The belief essentially is that the variety of such an artificial situation is two, either the standard was met or it was not. But manufacturing operations are not artificial situations; manufacturing operations interact among each other and with the environment to form a world situation of high variety.

Following Beer's critique of orthodox control systems, as described in the Review of the Literature, the Work Measurement system corresponds to the M1 model, with subdivisions which mirror the individual manufacturing operations, or tasks, within the overall organization. In addition, each operation or task is further divided into basic movements which are the basis for the data gathering and/or predetermined time standards found in published tables such as MTM. The Arthur and Young study, mentioned in Chapter Two, gives an MTM-1 example of the operation, "Tighten nut with open end wrench," which consists of such basic movements as reach for open end wrench, grasp wrench, regrasp for control, move wrench to other hand (2:50). Each of these basic movements corresponds to a subdivision of an M1-type model which is, in turn, a subdivision of the larger M1 model of the manufacturing operation. The detail is clearly minute and the necessity of continuous ad-hoc control, in the form of data base updates and Time Standard revisions, is obvious. What Work Measurement amounts to is, as Beer describes, the attempt to exhaustively enumerate the

proliferating variety of the world situation. The large data bases associated with Work Measurement systems (e.g., MTM-M contains approximately 5000 lines of sequence data (2:95)) and the continual need for revision of efficiency factors and standards indicate the symptoms of the pathologies of orthodox control. Hypotheses three and four are also confirmed.

F. Diagnostic Summary

Work Measurement is an orthodox, algorithmic, suboptimal control technique arising out of traditional cost accounting approaches to measuring and controlling operations. Although the Time Standards and associated work measurement data are derived by the defense contractor, the overall measurement and control scheme embodied in MIL-STD-1567 does not afford the contractor the opportunity to participate in the design of this System TWO function, consequently requisite variety in the control mechanism is not achieved. In addition, the work measurement approach does not account for dependent events and statistical fluctuations within the manufacturing operation as a whole; intrinsic variances therefore exist within both the standards and the expectations for systemic performance. Finally, considering the problematic environment of the contractor, which exists today as a non-viable defense market, we have established a weapons

procurement system which will not allow the contractor to establish throughput and also forces the contractor, through fiat, to continue to concentrate only on cost cutting despite the TQM claims to the contrary. We cannot fully resolve the shortcomings of work measurement and other cost-accounting tools now required of the contractor by DOD without recognizing the need to create a viable defense market but the works of both Beer and Goldratt clearly indicate the need for moving from the cost world to the throughput world, with a cybernetic system for management and control of operations, in the interest of maintaining the viability of the defense system.

V. Prescription, Conclusions and Recommendations

A. Introduction

This chapter will suggest a prescription for the pathologies noted in Work Measurement in Chapter Four. In addition, conclusions and recommendations drawn from the theoretical cybernetic analysis of Work Measurement will be discussed relative to the four research hypotheses set forth in Chapter One.

B. Prescription

Development of a cybernetic system for controlling operations is not as elusive as it may initially sound. The first step is to develop quantified flow charts (QFCs) of the organization of interest to identify process flows, potential bottlenecks, and the interrelationships among the individual operations. Once complete, these QFCs provide the basis for formulating M1a, the structural model of the organization as described in Chapter Two. With the availability of simulation packages, such as SLAM II used in the Chapter Four example, M1a is found to consist of the simulation code representing the queues, servers, and processes of the organization and M1b is comprised of the estimated activity or process times which are typically already available within the organization as engineering or manufacturing estimates. The key difference with the cybernetic control system is that

the initial estimates for the process times which comprise Mlb are not important from the control standpoint; these initial estimates merely form the basis for subsequent predictive models based upon the black box outputs. In other words, pre-determined time standards are not required to initiate and maintain management control of operations provided the cybernetic system for control, as described in Chapter Two is in place. One need only to establish Mla and Mlb from the knowledge base existing within the corporation and make use of the Levels and Measures of Achievement as process outputs to identify areas for management attention.

Development of Mla and Mlb, together with simulation runs and pilot production operations could easily be accomplished as part of Full-Scale development (FSD) activities to provide a basis for labor estimates in the Production phase of the program. This approach has the added benefit of both identifying producibility problems within FSD (something that's not always done now) and providing a much more reliable and timely basis for the production labor estimates. Typically the labor estimates for the first two or three lots of full-rate production are based on engineering estimates; MIL-STD-1567 tacitly acknowledges this in the evolutionary period granted for evolving Type II Standards into Type I Standards. Simulation, possibly augmented by pilot production, during FSD, with the establishment of the system for control, could provide a much more reliable basis for production labor estimates which

could be used in the negotiation of Lot 1. In addition, over time, the company will have been able to develop statistical classifications for the various process within the plant. Unless the equipment in use changes, or the fundamental process flows change, these classifications will remain valid for the life of the process, regardless of the configuration of the final product. What results is a predictive model which is independent of product and may therefore be employed to quickly and accurately formulate an estimate for any output without resorting to huge data bases for detailed job design. Further, if equipment or fundamental process flows do change, only the pertinent portions of M1a and M1b require update; continuous process improvement and elevation of systemic constraints is therefore possible without the need to maintain large amounts of historical process data and overhaul of the data base to accommodate operational flow changes. The reactive capability of the contractor is clearly enhanced.

C. Regarding the Hypotheses

The market, or problematic environment, faced by the defense contractor today presents an enormous variety challenge. Top-down directed measurement and control schema such as MIL-STD-1567 constrains the ability of the contractor to generate his own variety to achieve requisite variety with his problematic environment. Up one level of recursion from

the defense contractor, the DOD itself today faces a problematic environment also of extremely high variety; threats continue to change and evolve at an accelerating pace as both technology and the world political situation churn ahead into unknown and seemingly unpredictable states. With these increases in the variety of the environment, we can no longer afford to proliferate measurement and control schema within the defense procurement system which constrain the ability of the subsidiary viable systems to generate variety. Ashby's Law of Requisite Variety and the works of Stafford Beer clearly demonstrate the need to employ the variety of the lower levels of recursion within the recursive dimension to enhance the variety of the total system and achieve requisite variety with the problematic environment. To do otherwise is to threaten the continued viability of the existing system.

Without a viable market for defense products to constitute a discernable demand, the defense contractor's throughput cannot be set. Without an estimation of throughput, QFCs cannot be constructed and bottlenecks cannot be identified. Lacking in the knowledge of the interaction of the individual operations which comprise the overall manufacturing process and the whereabouts of the systemic constraints or bottlenecks, suboptimization techniques such as MIL-STD-1567 have evolved in the attempt to gather all possible information on all possible processes and their states. As the variety of the environment continues to

increase, the reactive capability needed to generate internal variety within the contractor and SPO organizations is constrained to the gathering of more data and the determination of which data fit a particular situation; requisite variety, stability, and the ensurance of viability is never achieved. Stafford Beer's VSM and Goldratt's Theory of Constraints demonstrate the need for autonomy of the subsidiary viable systems with only that amount of constraint necessary to ensure systemic cohesion. Work Measurement, by prescribing the control mechanism which the contractor shall use to manage and control labor-intensive operations, exceeds that minimal constraint necessary to ensure cohesion.

Reduction in weapon systems cost is a by-product of process improvement under autonomic operations. The focus on operational expense, or cost, as a means of control has been superseded by the DOD's own TQM philosophy yet the use of MIL-STD-1567, based on cost as a measure of performance, is still mandated within the defense procurement system. Implicit in MIL-STD-1567 is a suboptimal perspective which fails to recognize the global goal of the system. Through its algorithmic methods of prescribing in detail the basic motions and times involved in even the most rudimentary operations, Work Measurement constrains not only the worker but also the process of ongoing improvement which is vital to variety generation and results, ultimately, in lower-cost weapon systems.

D. Summary and Recommendations

Construction of a cybernetic system for controlling operations is possible within the defense contractor organization from existing knowledge and experience with past operations. The computer technology and simulation packages also exist to facilitate the construction of the cybernetic models M1a and M1b, together with the statistical procedures to construct and operate the black boxes. In addition, the literature suggests that the size and scope of the computer operations required to support the cybernetic system for control is far less than that required to maintain the databases for Work Measurement systems as evidenced by the applications already made to real-life operations by Beer and others.

In summary, cybernetic theory and Stafford Beer's VSM, and the measurements suggested by Goldratt in the Theory of Constraints appear to provide a sound framework for the construction of a cybernetic control system suitable not only for operations but which can also fulfill the reporting requirements of higher levels of recursion while enhancing the variety at all levels within the recursive dimension. Given the choice between the continued use and proliferation of suboptimal control techniques like MIL-STD-1567 or the establishment and promotion of systemic, cybernetic control systems which employ subsidiary system's variety in the service of management to ensure viability, it would certainly

benefit DOD to investigate the latter in a pilot procurement program. The next step in the evolution of the theoretical approach described in this thesis is to conduct an actual application via a joint effort between the SPO and the contractor. Mere research of historical data on programs to ascertain what might have been done if a cybernetic system would have been in operation, vice the work measurement system and all other associated cost-control techniques, cannot provide proper insight into the benefits of such an undertaking; the conditions, events, and interactions among the participants cannot be adequately reconstructed for a proper comparison. The final recommendation from this research is therefore an experimental application of cybernetic theory to a particular defense acquisition program.

Appendix A: Glossary

Actuality	A cybernetic measure of "what we are managing to do now, with existing resources, under existing constraints" (4:163)
Algorithmic	Rule-based, methodical, a-prior, stepwise procedure with the objective of situational variety reduction
Amplifier	"A device that increases variety." (7:35)
Attenuator	"A device that reduces [or delimits] variety" (7:35)
Autonomy	"The freedom of an imbedded subsystem to act on its own initiative, but only within the framework of action determined by the purpose of the total system" (7:105)
Bottleneck	"Resource whose capacity is equal to or less than the demand placed upon it" (17:137-138)
Capability	A cybernetic measure of "what we could be doing now with existing constraints if we really worked at it" (4:163)
Common Cause of Variation	A feature of a process or system inherent in its design which gives rise to random variation in output within some predictable range. Also seen as the cause of variation in systemic output after all sources of special causes of variation have been removed or accounted for
Cybernetic	Pertaining to the field of cybernetics, the science of effective organization and control
Heuristic	Variety-expansive with the objective of enlightened search
Latency	"The ratio of capability to potentiality" (8:293)

Metasystem	"A system over and beyond a system of lower logical order" (7:134)
Oscillation	"Failing to settle down in homeostatic equilibrium" (7:71)
Performance	"The ratio of actuality to potentiality" (8:293) Also the "product of latency and productivity" (4:163)
Potentiality	A cybernetic measure of "what we ought to be doing by developing our resources and removing constraints, although still operating within the bounds of what is already known to be feasible" (4:163)
Productivity	"The ratio of actuality to capability" (8:293)
Requisite Variety	The amount of variety a system must absorb to cope with the complexity with which it is faced
Special Cause of Variation	Something which causes variation in the output of a processor system which is statistically significant in that it cannot be attributed to randomness or common cause
Variety	The cybernetic measure of the number of possible states a system may attain which indicates its relative complexity. Note that this may be expressed as an ordinal measure
Viability	The capability of a system to maintain a separate existence within a specified environment (8:113)

Appendix B: SLAM II Program and Output

PROGRAM

```
GEN,VORE,DEPEVEN,8/14/90,,,,,,72;
LIMITS,5,3,500;
NETWORK;
;
;
;   THIS NETWORK IS A SERIES OF FIVE DEPENDENT ACTIVITIES,
;   EACH WITH AN EXPECTED TIME TO COMPLETION WHICH IS A
;   NORMAL RANDOM VARIABLE DRAWN FROM THE SAME DISTRIBUTION.
;
;
;   CREATE,5,0,1;           CREATE RAW MATERIAL
;   QUEUE(1),0;            WIP FOR ACTIVITY ONE
;   ACT/1,RNORM(5,0.5,2);   ACTIVITY ONE
;   QUEUE(2),0;            WIP FOR ACTIVITY TWO
;   ACT/2,RNORM(5,0.5,2);   ACTIVITY TWO
;   QUEUE(3),0;            WIP FOR ACTIVITY THREE
;   ACT/3,RNORM(5,0.5,2);   ACTIVITY THREE
;   QUEUE(4),0;            WIP FOR ACTIVITY FOUR
;   ACT/4,RNORM(5,0.5,2);   ACTIVITY FOUR
;   QUEUE(5),0;            WIP FOR ACTIVITY FIVE
;   ACT/5,RNORM(5,0.5,2);   ACTIVITY FIVE
;   ASSIGN,XX(5)=TNOW-ATRI(1);
;
;   COLLECT STATISTICS ON TOTAL TIME IN SYSTEM AND GRAPHICALLY
;   DISPLAY THE RESULTS
;
;
;   TERM;
;   ENDNETWORK;
INIT,0,300;
RECORD,TNOW,SIMULATION TIME,,B;
VAR,XX(5),T,TIME IN SYSTEM;
FIN;
```

OUTPUT

RECORDING OF PLOTS/TABLES

PLOT/TABLE NUMBER 1

INDEPENDENT VARIABLE:	TNOW
IDENTIFIER:	SIMULATION TIME
DATA STORAGE UNIT:	NSET/QSET
DATA OUTPUT FORMAT:	PLOT AND TABLE
TIME BETWEEN PLOT POINTS (DTPLT):	0.5000E+01
STARTING TIME OF PLOT (TTSRT):	0.0000E+00
ENDING TIME OF PLOT (TTEND):	0.3000E+03
DATA POINTS AT EVENTS (KKEVT):	YES

DEPENDENT VARIABLES

VARIABLE	SYM	IDENTIFIER	LOW ORD VALUE	HIGH ORD VALUE
XX(5)	T	TIME IN SYSTEM	MIN NEAR 0.0E+00	MAX NEAR 0.0E+00

RANDOM NUMBER STREAMS

STREAM NUMBER	SEED VALUE	REINITIALIZATION OF STREAM
1	428956419	NO
2	1954324947	NO
3	1145661099	NO
4	1835732737	NO
5	794161987	NO
6	1329531353	NO
7	200496737	NO
8	633816299	NO
9	1410143363	NO
10	1282538739	NO

INITIALIZATION OPTIONS

BEGINNING TIME OF SIMULATION (TTBEG):	0.0000E+00
ENDING TIME OF SIMULATION (TTFIN):	0.3000E+03
STATISTICAL ARRAYS CLEARED (JJCLR):	YES
VARIABLES INITIALIZED (JJVAR):	YES
FILES INITIALIZED (JJFIL):	YES

NSET/QSET STORAGE ALLOCATION

DIMENSION OF NSET/QSET (NNSET):	5000
WORDS ALLOCATED TO FILING SYSTEM:	3500
WORDS ALLOCATED TO VARIABLES:	569
WORDS AVAILABLE FOR PLOTS/TABLES:	931

INTERMEDIATE RESULTS

S L A M I I S U M M A R Y R E P O R T

SIMULATION PROJECT DEPEVEN

BY VORE

DATE 8/14/1990

RUN NUMBER 1 OF 1

CURRENT TIME 0.3000E+03

STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

FILE STATISTICS

FILE NUMBER	LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAIT TIME
1	QUEUE	0.077	0.267	1	1	0.379
2	QUEUE	0.819	0.710	2	1	4.162
3	QUEUE	0.138	0.345	1	0	0.727
4	QUEUE	0.052	0.223	1	1	0.280
5	QUEUE	0.140	0.347	1	0	0.776
6	CALENDAR	5.685	0.764	7	6	3.194

SERVICE ACTIVITY STATISTICS

ACT NUM	ACT START	LABEL OR NODE	SER CAP	AVERAGE UTIL	STD DEV	CUR UTIL	AVERAGE BLOCK	MAX IDL TME/SER	MAX BSY TME/SER	ENT CNT
1	ACTIVITY	ONE	1	0.967	0.18	1	0.00	0.95	84.37	59
2	ACTIVITY	TWO	1	0.969	0.17	1	0.00	4.75	232.76	57
3	ACTIVITY	THR	1	0.948	0.22	1	0.00	10.12	51.98	56
4	ACTIVITY	FOU	1	0.896	0.31	1	0.00	14.50	35.87	54
5	ACTIVITY	FIV	1	0.905	0.29	1	0.00	19.20	82.33	53

***TABLE NUMBER 1**
RUN NUMBER 1

SIMULATION TIME	TIME IN SYSTEM
0.0000E+00	0.0000E+00
0.5000E+01	0.3000E+00
0.1000E+02	0.0000E+00
0.1500E+02	0.0000E+00
0.2000E+02	0.0000E+00
0.2500E+02	0.2394E+02
0.3000E+02	0.2408E+02
0.3500E+02	0.2427E+02
0.4000E+02	0.2427E+02
0.4500E+02	0.2503E+02
0.5000E+02	0.2548E+02
0.5500E+02	0.2520E+02
0.6000E+02	0.2655E+02
0.6500E+02	0.2703E+02
0.7000E+02	0.2721E+02
0.7500E+02	0.2709E+02
0.8000E+02	0.2708E+02
0.8500E+02	0.2749E+02
0.9000E+02	0.2657E+02
0.9500E+02	0.2822E+02
0.1000E+03	0.2759E+02
0.1050E+03	0.2862E+02
0.1100E+03	0.2879E+02
0.1150E+03	0.2979E+02
0.1200E+03	0.2947E+02
0.1250E+03	0.2947E+02
0.1300E+03	0.2971E+02
0.1350E+03	0.2965E+02
0.1400E+03	0.2973E+02
0.1450E+03	0.2999E+02
0.1500E+03	0.2989E+02
0.1550E+03	0.2989E+02
0.1600E+03	0.3117E+02
0.1650E+03	0.3220E+02
0.1700E+03	0.3255E+02
0.1750E+03	0.3171E+02
0.1800E+03	0.3223E+02
0.1850E+03	0.3259E+02
0.1900E+03	0.3288E+02
0.1950E+03	0.3302E+02
0.2000E+03	0.3257E+02
0.2050E+03	0.3281E+02
0.2100E+03	0.3248E+02
0.2150E+03	0.3312E+02
0.2200E+03	0.3247E+02
0.2250E+03	0.3246E+02

0.2300E+03	0.3326E+02
0.2350E+03	0.3280E+02
0.2400E+03	0.3402E+02
0.2450E+03	0.3402E+02
0.2500E+03	0.3446E+02
0.2550E+03	0.3496E+02
0.2600E+03	0.3451E+02
0.2650E+03	0.3464E+02
0.2700E+03	0.3464E+02
0.2750E+03	0.3533E+02
0.2800E+03	0.3601E+02
0.2850E+03	0.3662E+02
0.2900E+03	0.3658E+02
0.2950E+03	0.3604E+02
0.3000E+03	0.3630E+02
0.3000E+03	0.3630E+02

MINIMUM 0.0000E+00

MAXIMUM 0.3662E+02

PLOT NUMBER 1
 RUN NUMBER 1

SCALES OF PLOT
 T=TIME IN SYST0.000E+00 0.183E+02 0.366E+02
 0 10 20 30 40 50 60 70 80 90 100 DUPS
 SIMULATION TIME

0.0000E+00	T				+						+
0.5000E+01	T				+						+
0.1000E+02	T				+						+
0.1500E+02	T				+						+
0.2000E+02	T				+						+
0.2500E+02	+				+						+
0.3000E+02	+				+						+
0.3500E+02	+				+						+
0.4000E+02	+				+						+
0.4500E+02	+				+						+
0.5000E+02	+				+						+
0.5500E+02	+				+						+
0.6000E+02	+				+						+
0.6500E+02	+				+						+
0.7000E+02	+				+						+
0.7500E+02	+				+						+
0.8000E+02	+				+						+
0.8500E+02	+				+						+
0.9000E+02	+				+						+
0.9500E+02	+				+						+
0.1000E+03	+				+						+
0.1050E+03	+				+						+
0.1100E+03	+				+						+
0.1150E+03	+				+						+
0.1200E+03	+				+						+
0.1250E+03	+				+						+
0.1300E+03	+				+						+
0.1350E+03	+				+						+
0.1400E+03	+				+						+
0.1450E+03	+				+						+
0.1500E+03	+				+						+
0.1550E+03	+				+						+
0.1600E+03	+				+						+
0.1650E+03	+				+						+
0.1700E+03	+				+						+
0.1750E+03	+				+						+
0.1800E+03	+				+						+
0.1850E+03	+				+						+
0.1900E+03	+				+						+
0.1950E+03	+				+						+
0.2000E+03	+				+						+
0.2050E+03	+				+						+
0.2100E+03	+				+						+
0.2150E+03	+				+						+

0.2200E+03	+				+					T	+
0.2250E+03	+				+					T	+
0.2300E+03	+				+					T	+
0.2350E+03	+				+					T	+
0.2400E+03	+				+					I'	+
0.2450E+03	+				+					T	+
0.2500E+03	+				+					T	+
0.2550E+03	+				+					T	+
0.2600E+03	+				+					T	+
0.2650E+03	+				+					T	+
0.2700E+03	+				+					T	+
0.2750E+03	+				+					T	+
0.2800E+03	+				+					T+	
0.2850E+03	+				+					T	
0.2900E+03	+				+					T	
0.2950E+03	+				+					T+	
0.3000E+03	+				+					T	
	0	10	20	30	40	50	60	70	80	90	100 DUPS

SIMULATION TIME

OUTPUT CONSISTS OF 62 POINT SETS (62 POINTS)
 STORAGE ALLOCATED FOR 465 POINT SETS (930 WORDS)
 STORAGE NEEDED FOR 62 POINT SETS (124 WORDS)

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Vita

Captain Daniel R. [REDACTED]

[REDACTED] He graduated from Alpena High School in Alpena, Michigan, in 1980, and attended Michigan Technological University where he received his Bachelor of Science Degree in Chemical Engineering in 1984. While attending Michigan Tech, he enrolled in the USAF ROTC program and received his commission as a Second Lieutenant upon graduation. Captain Vore began active duty with an assignment to ASD/RWQY, the TR-1/U-2 Aircraft Systems Program Office (SPO), as a TR-1 Aircraft Project Officer on 15 October 1984. During the period 15 October 1984 to 19 May 1989, Captain Vore held many SPO positions within the Reconnaissance Programs Directorate (ASD/RWQ) including TR-1/U-2 Aircraft Program Manager, Advanced Synthetic Aperture Radar (ASARS-II) Program Manager, Tactical Reconnaissance System (TRS) Business Manager, and Commanders' Tactical Terminal (CTT) Low-rate Initial Production (LRIP) Program Manager. In May 1989, Captain Vore entered the Air Force Institute of Technology to pursue a Master of Science Degree in Systems Management.

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